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**Westinghouse**

SCAN-CONVERSION STORAGE TUBE BASED UPON THE PERMACHON



Report Nr. 15

Final Report

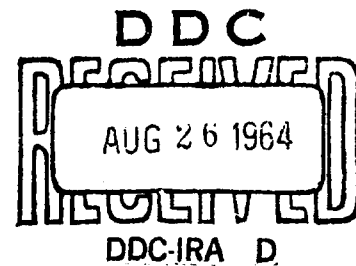
1 January 1964 to 31 March 1964

Contract Nr. DA-36-039-AMC-00149(E)

(Continuation of Contract Nr. DA-36-039-sc-85051)

Department of the Army Task Nr. 1G6-22001-A-005-03

U. S. Army Electronics Laboratories  
Fort Monmouth, New Jersey



**WESTINGHOUSE ELECTRIC CORPORATION  
ELECTRONIC TUBE DIVISION  
ELMIRA NEW YORK**

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SCAN-CONVERSION STORAGE TUBE BASED UPON THE PERMACHON

Report Nr. 15  
Final Report  
1 January 1964 to 31 March 1964

Objective: To study, conduct experimental investigations, and develop feasibility models of a scan-conversion storage tube utilizing electrical write-read transformation, wherein a photo-conductive target similar to that of the Permachon will be used as the storage mechanism.

Contract Nr. DA-36-039-AMC-00149(E)  
(Continuation of Contract Nr. DA-36-039-sc-85051)  
Department of Army Task Nr. IG6-22001-A-005-03

R. J. Doyle

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# PURPOSE

The purpose of this contract is to establish feasibility and demonstrate models of an electrical-input, electrical-output scan-conversion storage tube based upon a photoconductive readout target similar in principle to that used in the Westinghouse Electric Corporation's Permachon camera storage tube, to meet the objective specifications given in the Technical Guidelines, dated 1 April 1960, of the Electronic Components Department, USAEL, titled "Research and Development of a Scan-Conversion Storage Tube Based Upon the Permachon."

## ABSTRACT

Two types of scan-conversion storage tubes based upon the Permachon camera storage tube have been developed, and both tubes utilize a fiber-optics photon transfer (FOPT) target for the signal conversion mechanism.

The smaller of the two tubes, the WX 4640, is 16-1/2 inches long, 1-1/2 inches in diameter, and contains an FOPT target with a 3/4-inch-diameter useful area. The reading gun in this tube is electromagnetically focused and deflected, while the writing gun is electrostatically focused and electromagnetically deflected.

The large scan-converter, the WX 4821, is 31 inches long, 3 inches in diameter, and has an FOPT target with a 2-inch-diameter useful area. Both of the electron guns in this tube are electrostatically focused and deflected.

The WX 4640 has been developed to the point where it could be put into pilot production for utilization in some scan-conversion applications. The WX 4821, a more complex tube, has not been developed to the same extent, and additional work will have to be performed before this tube can be specified for particular applications.

This report summarizes all the development work performed on the Permachon scan-converters, including recently obtained data on charge-down subsequent to erasure, aperture-response, and flood-beam holding. Also included as an Appendix to this report are additional data on characteristics measured from the WL 7383 Permachon camera storage tube.

PUBLICATIONS, LECTURERS, REPORTS, AND  
CONFERENCES

Listed below are the publications, lectures, reports, and conferences resulting from the research and development of this contract.

Publications

- R. J. Doyle, "Permachon-Type Scan-Converters," 1963 IEEE International Convention Record, March, 1963, Part 3, pp. 48-56.
- R. J. Doyle, "A Scan-Conversion Tube Utilizing Fiber-Optics Photon Transfer," IEEE Transactions on Electron Devices, Vol. ED-10, No. 6, November, 1963, pp. 410-416.

Lectures

- "Permachon-Type Scan-Converters," 23 March 63, at the 1963 International Convention of the IEEE, at the Waldorf-Astoria Hotel in New York City, by R. J. Doyle

Reports

- Four Quarterly Progress Reports

Conferences

- The Contracting Officer's Technical Representative, Mr. M. E. Crost, visited the Image Tube Department of the Westinghouse Electric Corporation on 7 Feb 63, 30 July 63, 5 Dec 63, and 21 Apr 64, to review the contract.
- The Director of the Electron Tubes Division of USAEL, Mr. Kenton Garoff visited the Westinghouse Electronic Tube Division on 15 Aug. 63.
- Personnel of Westinghouse Electronic Tube Division, Image Tube Department, visited the Pickup, Display, and Storage Devices Section of USAEL, Fort Monmouth, on 23 Apr 63 and 4 Feb 64 to review the status of the contract.
- Mr. R. J. Doyle visited Mr. M. E. Sawyer of Sawyer Associates in Littleton Common, Mass., on 3 Jun 63 and 28 Sept 63 to discuss glass-rod supported deflectrons.

- Mr. R. J. Doyle visited Mosaic Fabrications, Inc., in Southbridge, Mass., on 3 Jun 63 to finalize the specifications for fiber-optics.

## FACTUAL DATA

### INTRODUCTION

The scan-converter tube is an electron device into which information can be introduced in one format and extracted simultaneously or at a later time in the same or a different format.

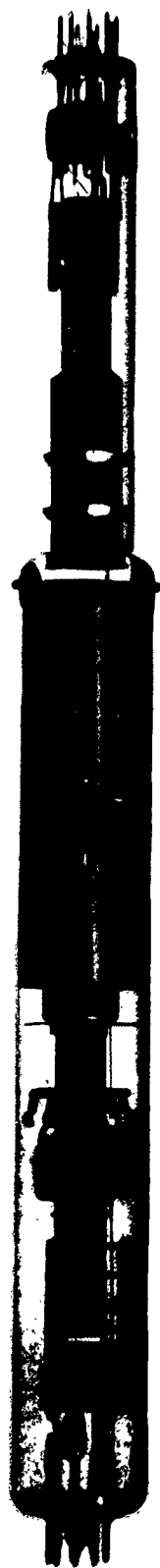
During the period of this and the preceding scan-converter contract two types of scan-conversion tubes based upon the Permachon camera storage tube were developed. Figure 1 is a photograph of the smaller of the two tubes, designated WX 4640, and Figure 2 shows the larger tube, designated WX 4821. Both of these tubes operate on the same principle of Fiber-Optics Photon Transfer (FOPT), but differ in target size and method of beam generation. The WX-4640 contains an all-electromagnetic reading gun, an electrostatically focused and electromagnetically deflected writing gun, and provides a useful target diameter of 3/4 inch. Both electron guns in the WX 4821 are electrostatically focused and deflected, and the target has a 2-inch diameter useful area.

In some of the early work performed on the scan-converter Electron-Bombardment-Induced-Conductivity (EBIC) targets were investigated; however, the majority of the development effort has been directed toward the FOPT-type target.

Included as an appendix to this report are data taken from the Permachon camera storage tube, which help to complete the study of the Permachon effect.

### PRINCIPLES OF OPERATION

The Permachon scan-converter consists basically of two electron guns and an interjacent FOPT target, all of which are incorporated in a single vacuum envelope. The writing electron gun produces a high-velocity electron beam, while the reading gun generates a low-velocity beam. The FOPT target consists of a fiber-optics disc that conducts light from the writing to the reading side of the target with little loss of energy. As shown in Figure 3,

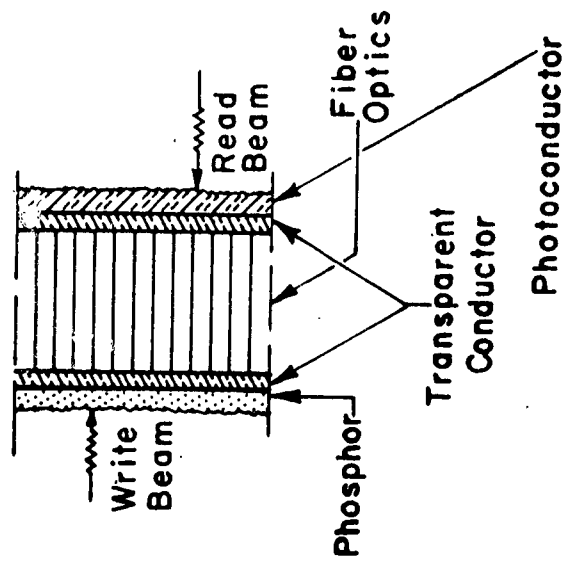


**Figure 1. WX 4640 Permachon Scan-Converter**



Figure 2. WX 4821 Permachon Scan-Converter





(Not to Scale)

Figure 3. Fiber-Optics Photon Transfer Target

both surfaces of the fiber-optics disc are coated with transparent conductive laminae, such as stannic oxide. One of these conductors serves as an electrode during the cataphoretic deposition of a fine-grain phosphor on the writing side of the target. This same conductor also provides an even potential distribution to the phosphor when it is bombarded by the writing beam. The other conductor beneath the photoconductor serves as the output signal electrode.

In the majority of targets constructed, the photoconductor is a long-storage type, and the phosphor is P-20, which has a short persistence and closely matches the spectral response of the photoconductor.

Under normal operating conditions, a potential difference is first placed across the unilluminated photoconductor by applying a positive potential (5 to 20V above the read-gun cathode) to the transparent conductor under the photoconductor and then charging the front surface of this photoconductor down to the reading-gun cathode potential (normally ground) by the deposition of low-velocity electrons from the reading gun.

When the high-velocity electron beam from the writing gun excites the phosphor deposited on the reverse side of the target, photons are emitted and transferred via the fiber-optics disc to the photoconductor. As in a vidicon, these photons increase the conductivity of the photoconductor material, so that electrons previously deposited on its front surface move easily to the higher potential of the conductive substrate. This causes the front surface of the illuminated photoconductor areas to rise in potential, so that, when the reading beam rescans the front surface of the photoconductor, it deposits electrons on these illuminated areas in proportion to the number of input photons. Those reading-beam electrons which are not deposited form a return beam that is collected by the positive elements of the reading gun.

The deposition by the scanning beam of varying quantities of electrons at each point across the photoconductor gives rise to the ac output signal. That is, the photoconductor, which consists of many parallel paths

of different conductivity, modulates the scanning beam in proportion to the input illumination.

After a portion of the reading-beam current passes through the illuminated photoconductor, it becomes a signal current and is carried by the conductive lamina beneath the photoconductor to an attached electrode, which, in turn, is connected through the wall of the scan-converter envelope. The output signal is fed through suitable video amplifiers and inter-connecting circuitry to either the control grid or cathode of a cathode-ray display tube. The scanning of the display tube is synchronized with the scanning of the scan-converter reading gun (the scanning of the writing gun is completely independent), so that each illuminated photoconductor area results in a proportionately bright area, in the proper location, on the scan-converted display.

Since the input and output currents travel in paths that are electrically separated by the glass fiber-optics, while light acts as the coupling mechanism, this type of target structure is very useful in scan-conversion tubes, and external signal separation is not required. The tube is thus analogous to a vidicon that is optically coupled to a cathode-ray display tube by an optical lens system. In this tube, however, the lens system is replaced by the fiber-optics disc and is enclosed in the one vacuum envelope.

#### TARGET DEVELOPMENT

During the term of this contract, target development was carried on using the smaller WX 4640-type scan-converter as a test vehicle, while the development of the larger electrostatic tube was carried on in parallel.

#### Target Mounting

A mechanical change was made in the method of mounting the target within the tube envelope. During the preceeding contract, a ceramic mounting assembly (See Figure 4) was utilized to hold the FOPT target and make electrical contact to the conductive laminae on both sides of the

1. FOPT Target
2. Centering Ring
3. Clamping Ring
4. 0-80 Bolt
5. 0-80 Nut

All dimensions in inches

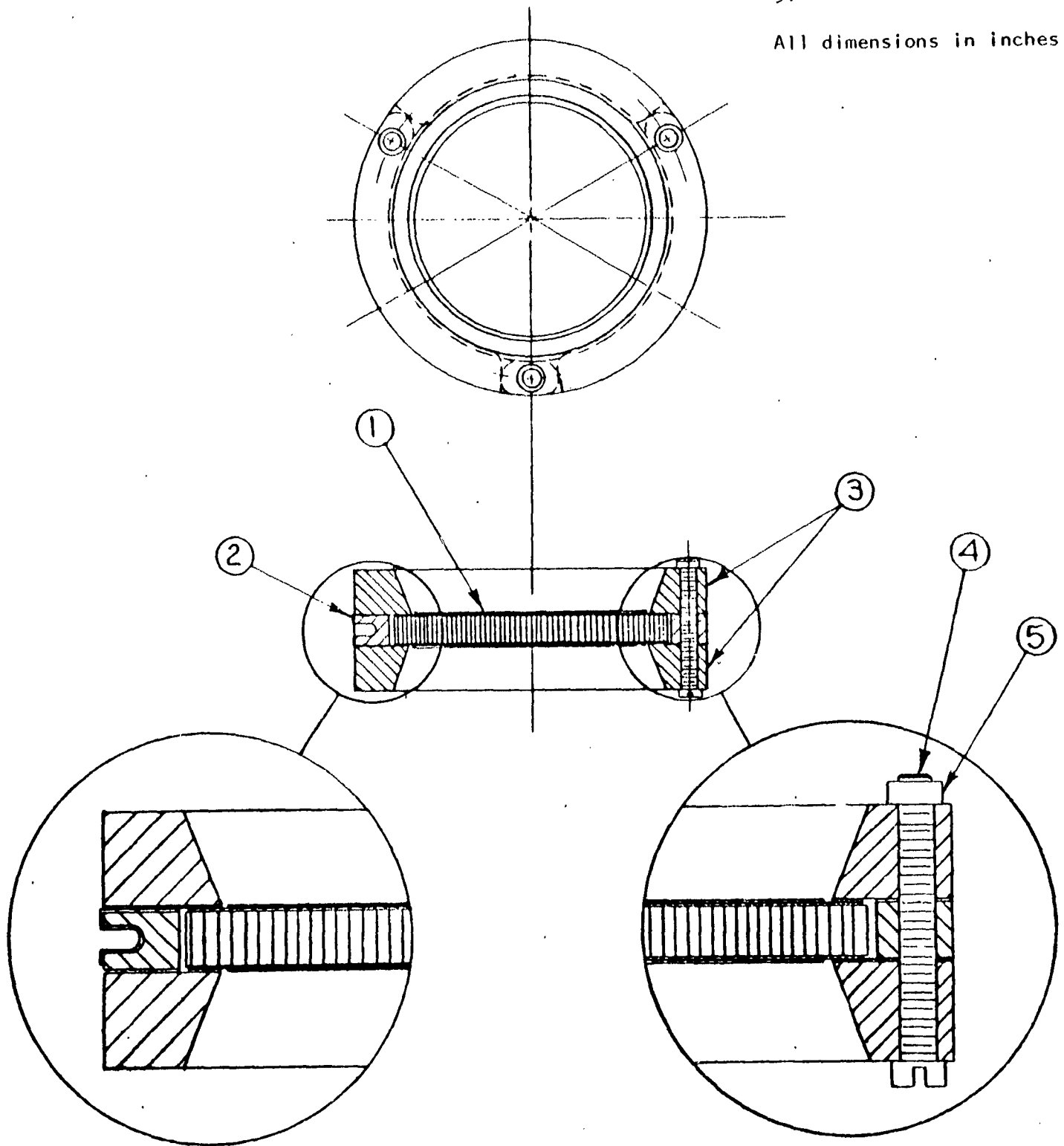


Figure 4. Ceramic Target Mounting Assembly

target. During this contract, the mounting was simplified by cutting slots directly into a slightly oversized fiber-optics disc as shown in Figure 5, for the WX 4640, and Figure 6, for the WX 4821. The three extra slots in the larger fiber-optics disc are used for mounting the collimating-mesh assembly. The new mounting has eliminated the need for ceramic rings which is significant when considering the larger target, where new and larger ceramics would have been necessary. It also reduces the mass of the target, making it inherently more rugged, better permits the use of an external light-flash for erasure, and reduces the necessity for close tolerances in the thickness of the fiber-optics disc.

#### Fiber-Optics

Several types of fiber-optics glasses were evaluated for use in FOPT targets. Lanthanum, Lead I, Lead II, Lanthanum with dark extramural absorption (EMA) cladding, and a special glass with a numerical aperture (N.A.) of 1.0 were obtained from Mosaic Fabrications, Inc. and stannic-oxide coated, with the result that only the lanthanum types could be coated to the required resistance of 200 ohms per square or lower.

The dark EMA fiber-optics were evaluated in scan-converters. The results of these studies showed that they had substantially better resolution, (see Figure 26); however, the domain lines in these discs contributed to a very discernible multi-hexagon pattern in the output video presentation.

The data taken from the resolution and conductive coating experiments showed that, although the overall resolution of the tube can be improved with the dark EMA, the clear 0.84 N.A. lanthanum glass must be used at this time, because it can be conductively coated to a low resistance and yet contributes no coherent noise pattern to the output video signal.

Barium-type glass has also been used, but because of its 0.67 N.A. it does not give as good resolution as the 0.84 N.A. clear lanthanum glass.

All Dimensions in Inches

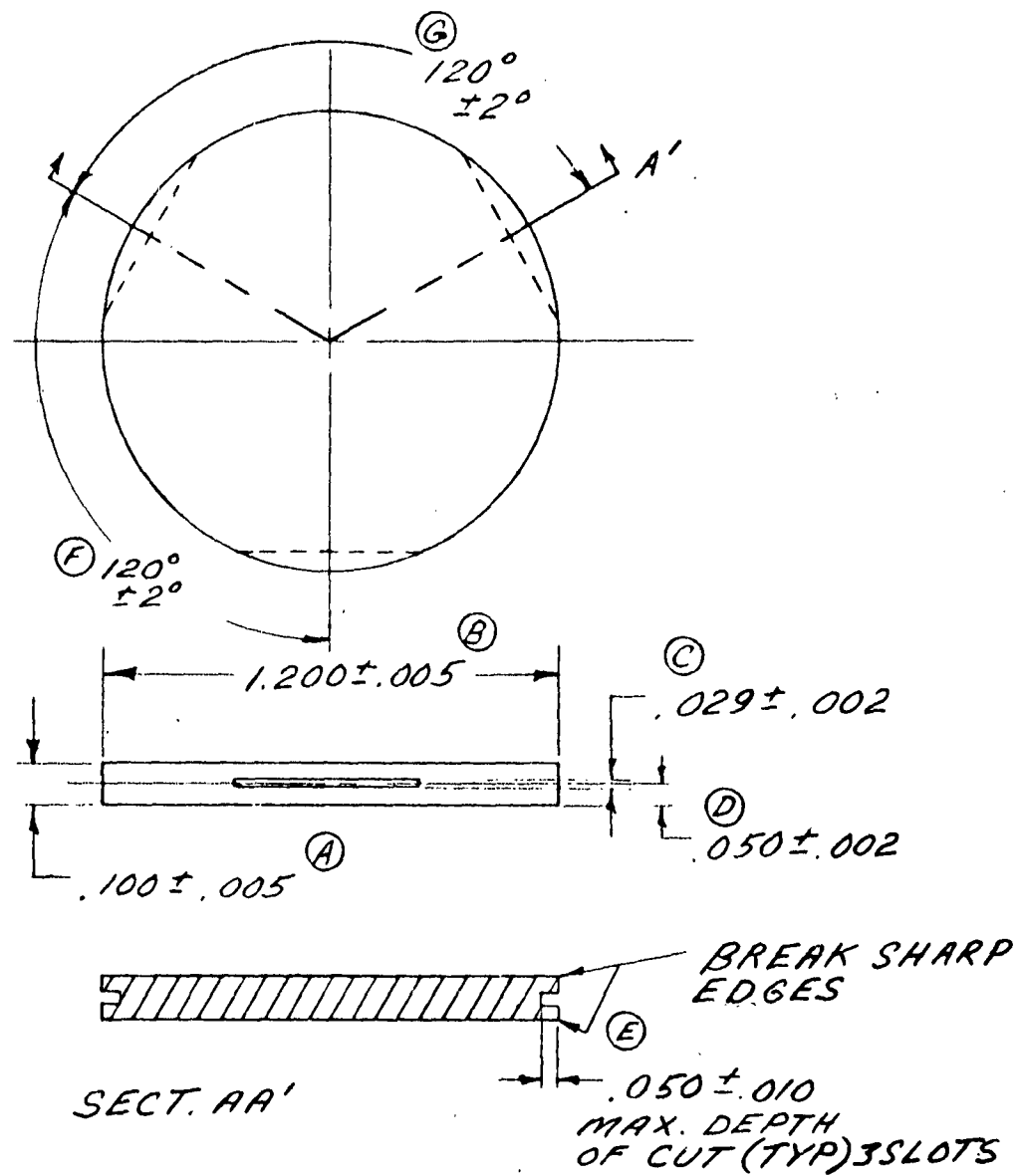


Figure 5. Slotted Fiber Optics Disc (WX 4640)

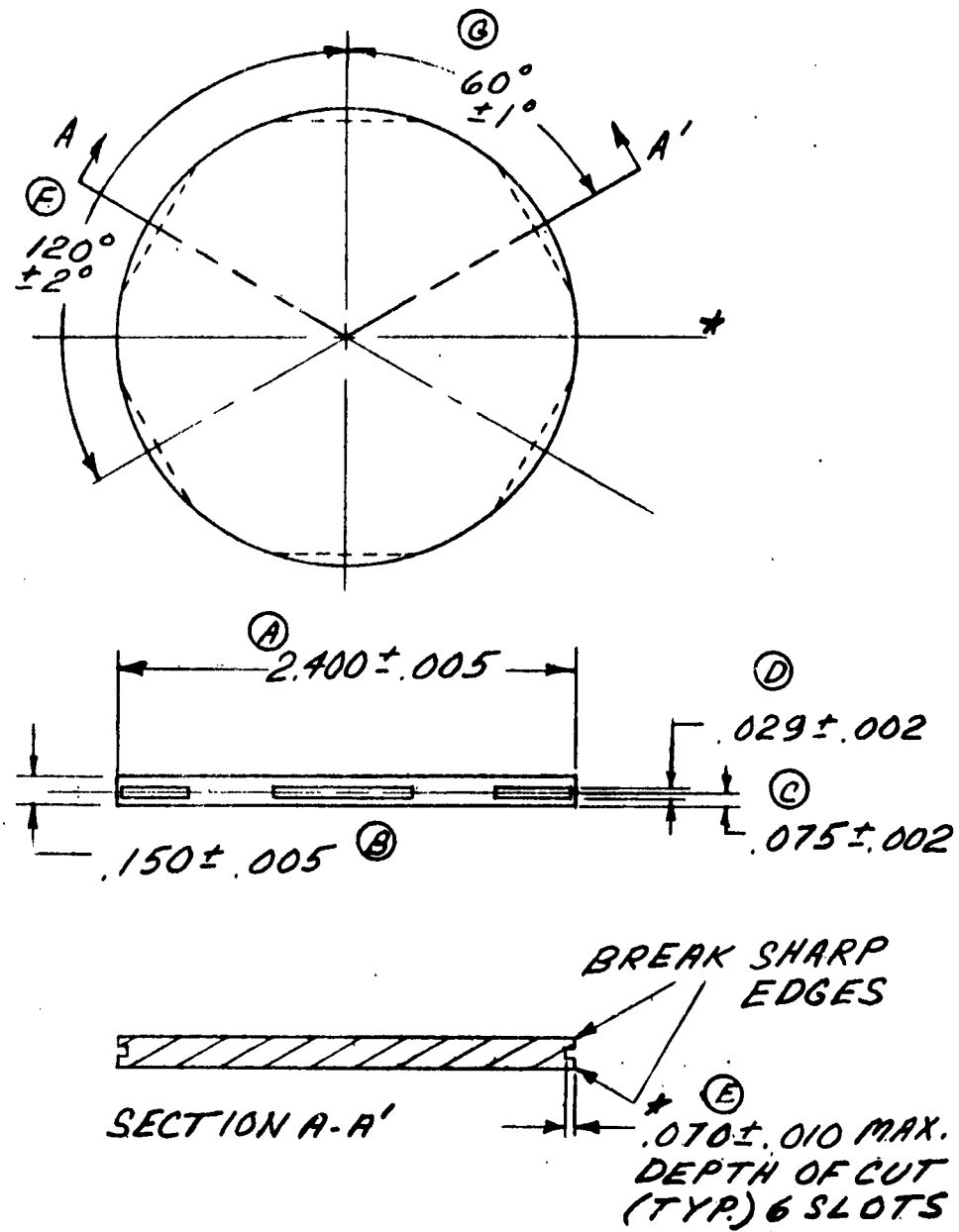


Figure 6. Slotted Fiber Optics Disc (WX 4821)

### Transparent Conductive Laminae

In the early phases of this development and at several times throughout this program, the problem of fiber-optics cracking during the stannic-oxide-coating process was encountered. However, during the final phase of the contract 10, 1.2-inch-diameter discs were coated on both sides in a continuous 8 hours per day operation over a two day period without a single crack. This experience indicates that stannic-oxide coating of fiber-optics is not the serious problem it was once thought to be.

### P-12 Phosphors

Attempts were made during the fourth and fifth quarterly periods to settle P-12 phosphor, since the results of experiments with cathode-ray tubes and Permachon camera storage tubes showed that the decay of the P-12 worked well with the Permachon's ability to integrate. However, many difficulties were encountered in settling P-12, with the result that no complete scan-converter tubes with P-12 phosphor were made.

### STRUCTURE DEVELOPMENT

#### WX 4640

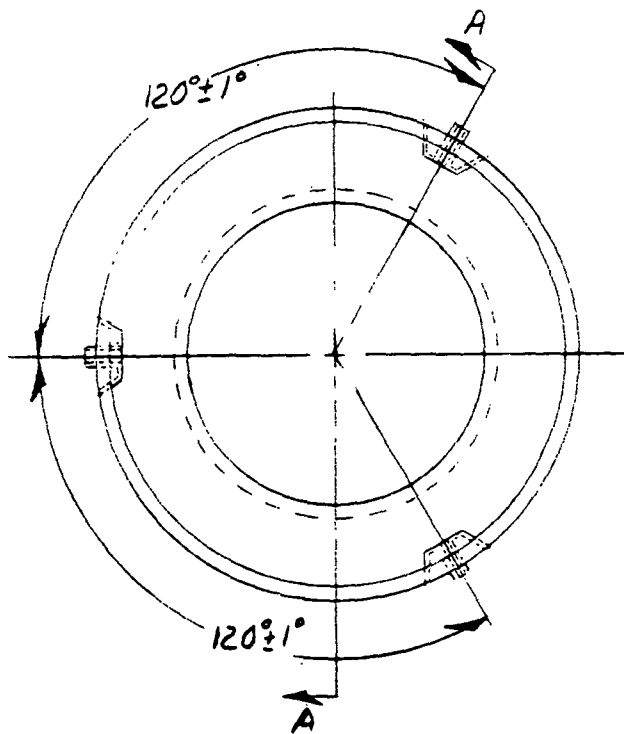
The structure of the WX 4640 was developed during the first scan-converter contract and remained virtually unchanged, except for the target, as was described earlier in this report. Details of the construction of this tube are contained in the Final Report on Contract DA-36-039-sc-85051.

#### WX 4821

The structure of the WX 4821 was completely developed during this contract. The WX 4821 contains two electrostatically focused and deflected electron guns and an interjacent FOPT target that is 2.4 inches in diameter. The guns were designed and first tested in cathode-ray tubes with P-20 output phosphors. Later these guns were incorporated in complete tubes.

Figure 7 is a drawing of the reading-gun bulb, and Figure 8 is a drawing of the writing-gun bulb. Once these bulbs have been assembled





1

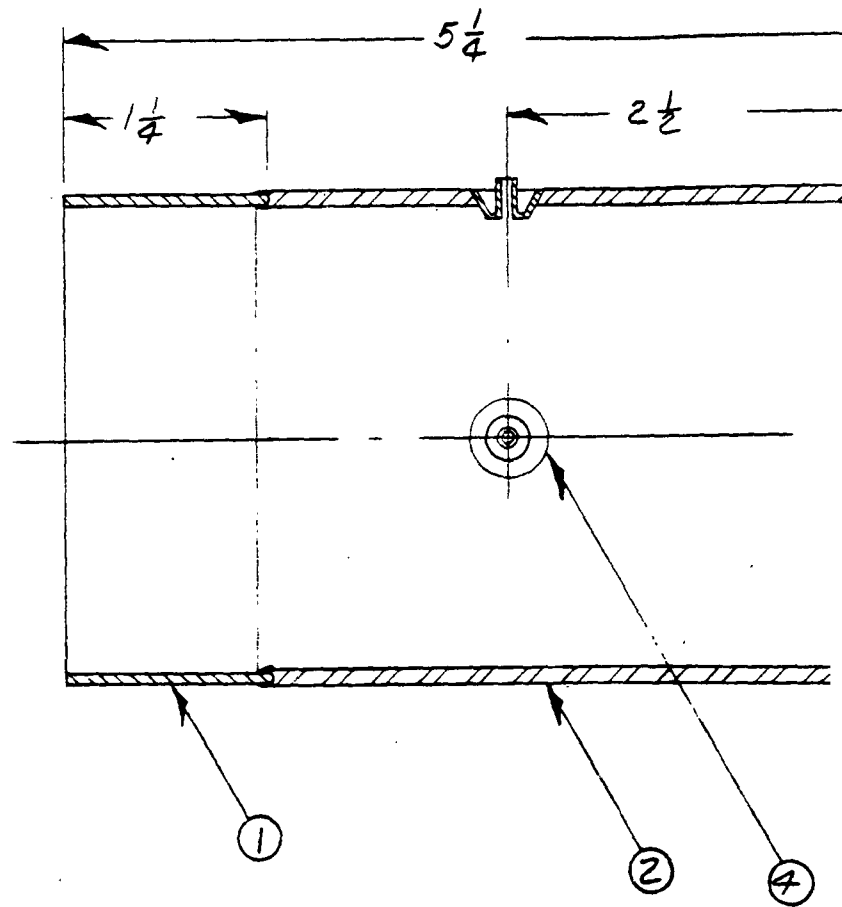


Figure 7. Reading-Gun B

1. Kovar Ring
2. 3-Inch Bulb
3. 2-Inch Bulb
4. Open Contact

All dimensions in inches

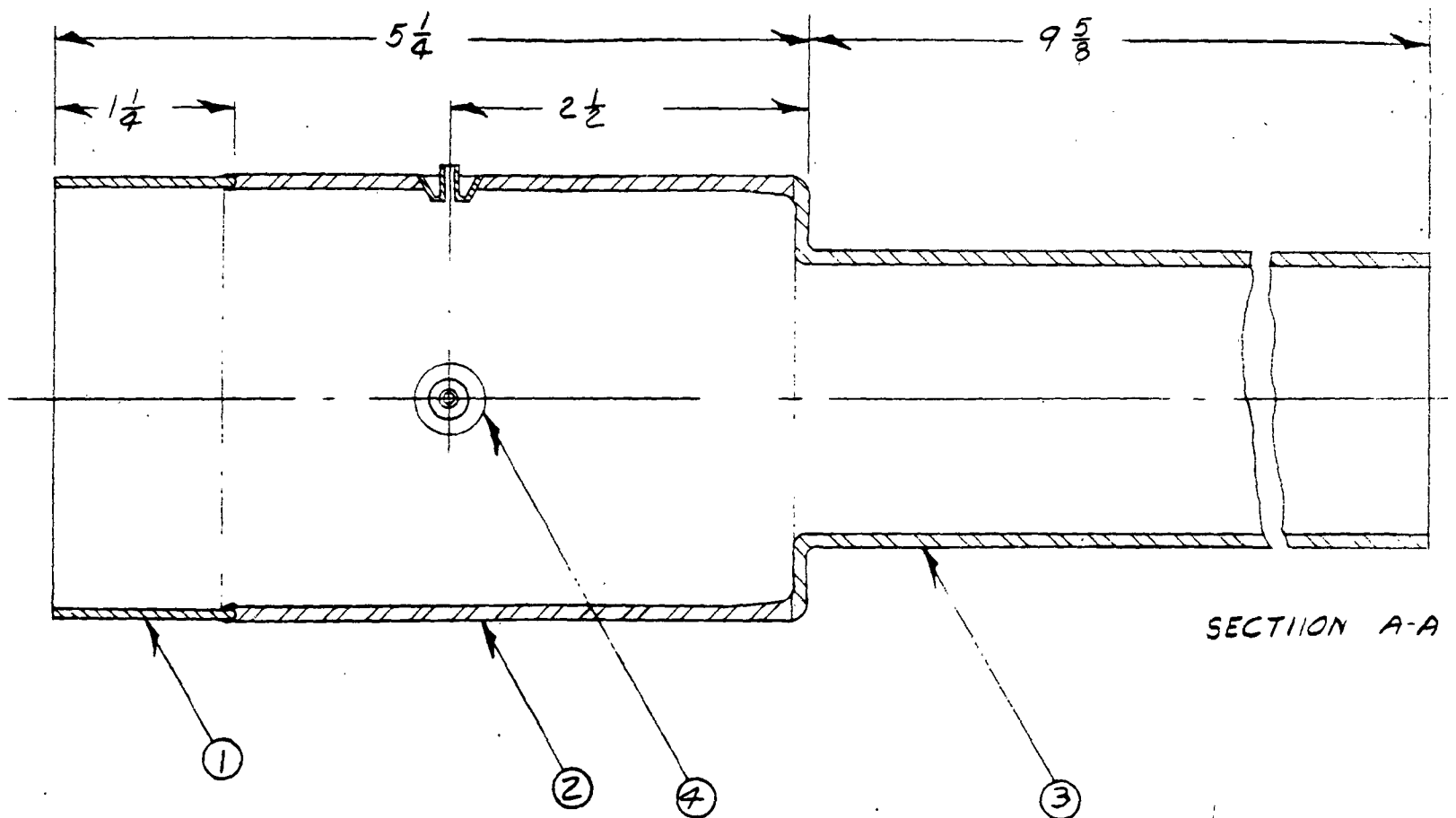
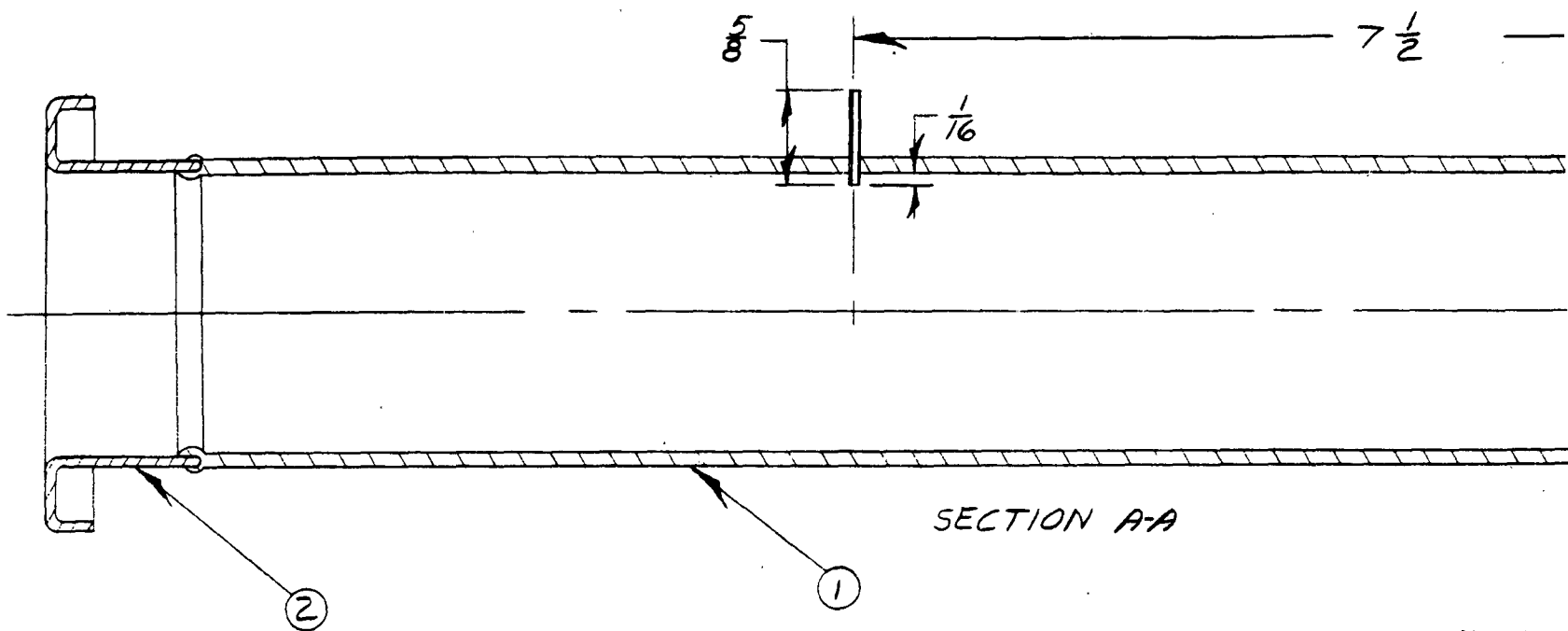


Figure 7. Reading-Gun Bulb

2



1. 2-Inch Bulb
  2. Kovar Flange
  3. Deflection Plate Contact Pin
- All dimensions in inches

1

Figure 8. Writing-Gun Bulb

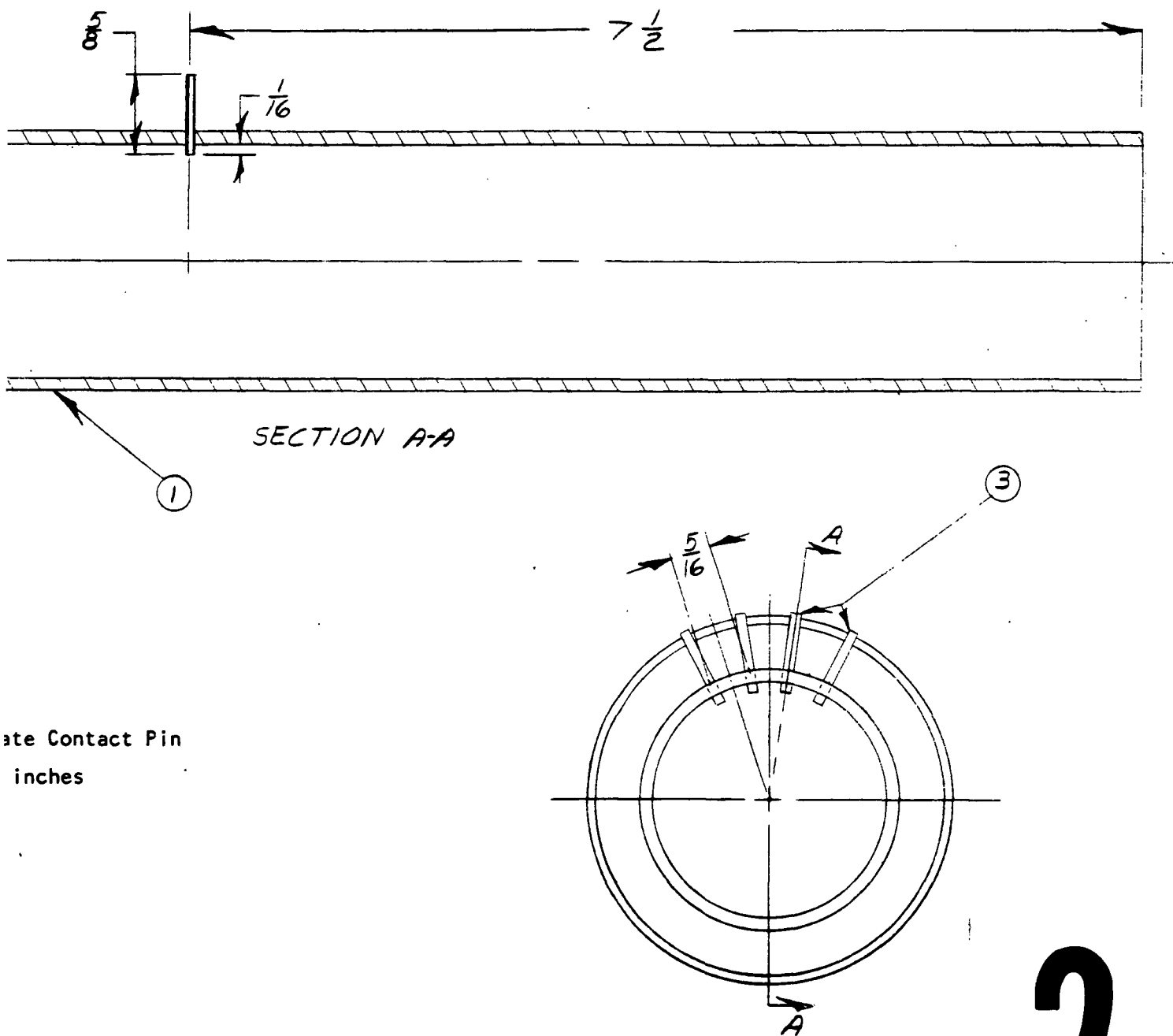


Figure 8. Writing-Gun Bulb

2

and annealed they are washed, aluminized, baked, and rewashed, and appear as shown in Figures 9 and 10. After the aluminizing, the reading gun is sealed into its bulb, as shown in Figure 11, and the writing gun as is shown in Figure 12. At this point in the procedure, each half of the tube is mounted into a separate larger glass envelope and vacuum baked at 300°C for approximately 48 hours. This is necessary since the tube cannot be baked once the photoconductor is mounted in place.

Figure 13 is a drawing of the complete target-mesh assembly. The fiber-optics disc is coated in the same manner as the smaller WX 4640 target, and the collimating-mesh assembly is attached by means of 3, 0-80 socket-head set-screws, which fit three of the slots in the fiber-optics disc.

The completed target-mesh assembly is placed upon a vertically adjustable mounting fixture, and the prebaked reading-bulb-and-gun assembly is brought down over the fixture, as shown in Figure 14. Once in place, three holding pins are slipped through the open eyelets in the bulb and into the slots in the fiber-optics. The pins are temporarily resistance-welded in place under the hood, and then the assembly is transported to the welding annex of the clean-room, where the close-over heliarc welds are made. This operation results in the target-bulb assembly shown in Figure 15.

The final assembly operation is a heliarc seam-weld which joins the two halves of the tube. Figure 16 is a photograph of the initial step in the joining process. First the reading portion of the tube is placed in the base of the fixture, while the writing section is held in a removable clamp assembly mounted above the main base, as shown in the photograph. Using this set-up, three spot welds are made 120° apart along the seam. With the two halves tacked together, the top portion of the fixture is removed, heat sinks are attached, and the seam-weld is made as the tube rotates on a turntable. The results of this operation are shown in Figure 17. The tube is assembled in this manner to insure that the photoconductor will be subjected to only a minimum amount of thermal energy.

1. Reading Bulb
2. Silver Paint
3. Aluminum

All dimensions in inches

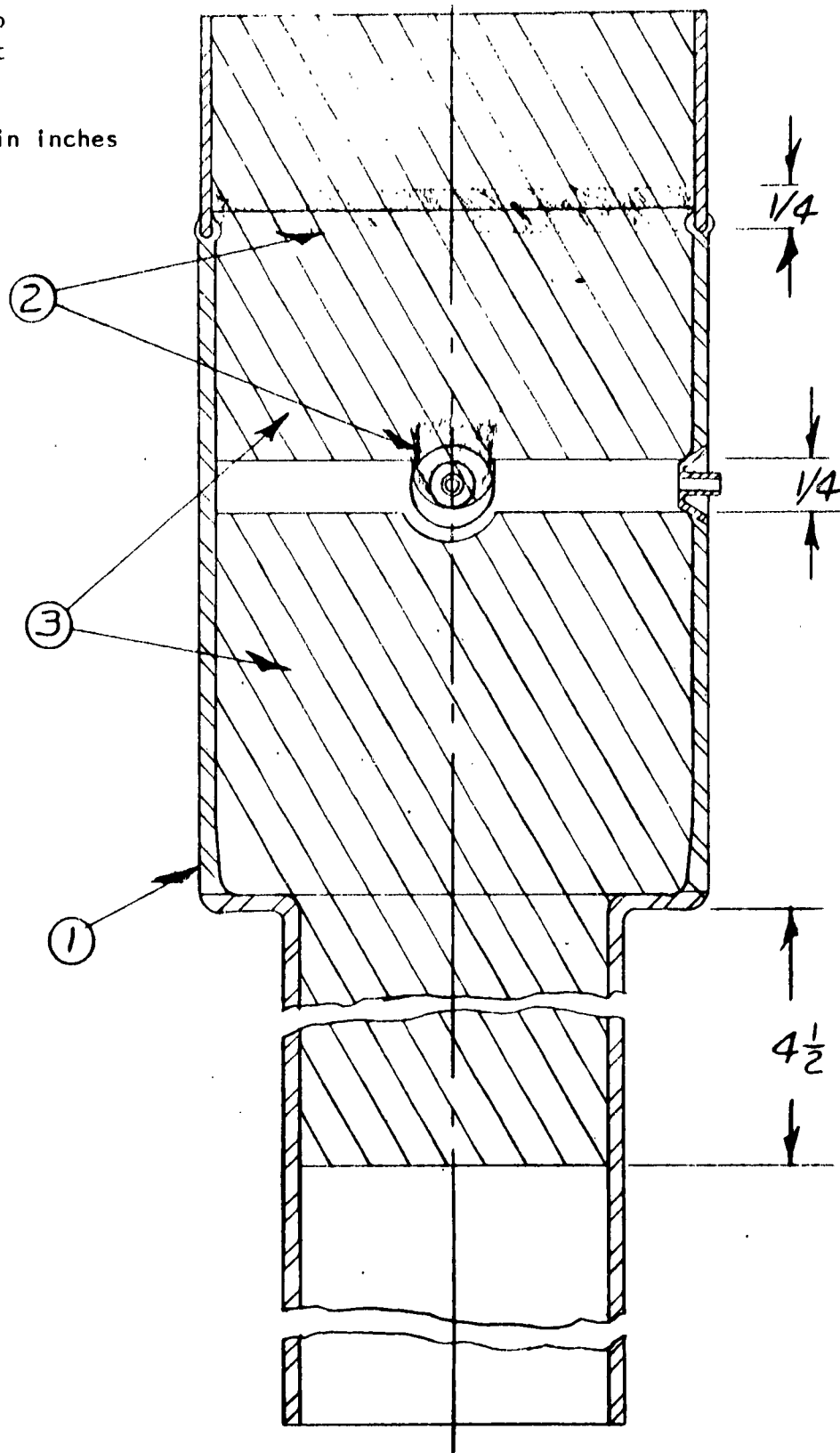


Figure 9. Aluminized Reading-Gun Bulb

1. Writing Bulb
2. Aluminum
3. Silver Paint

All dimensions in inches

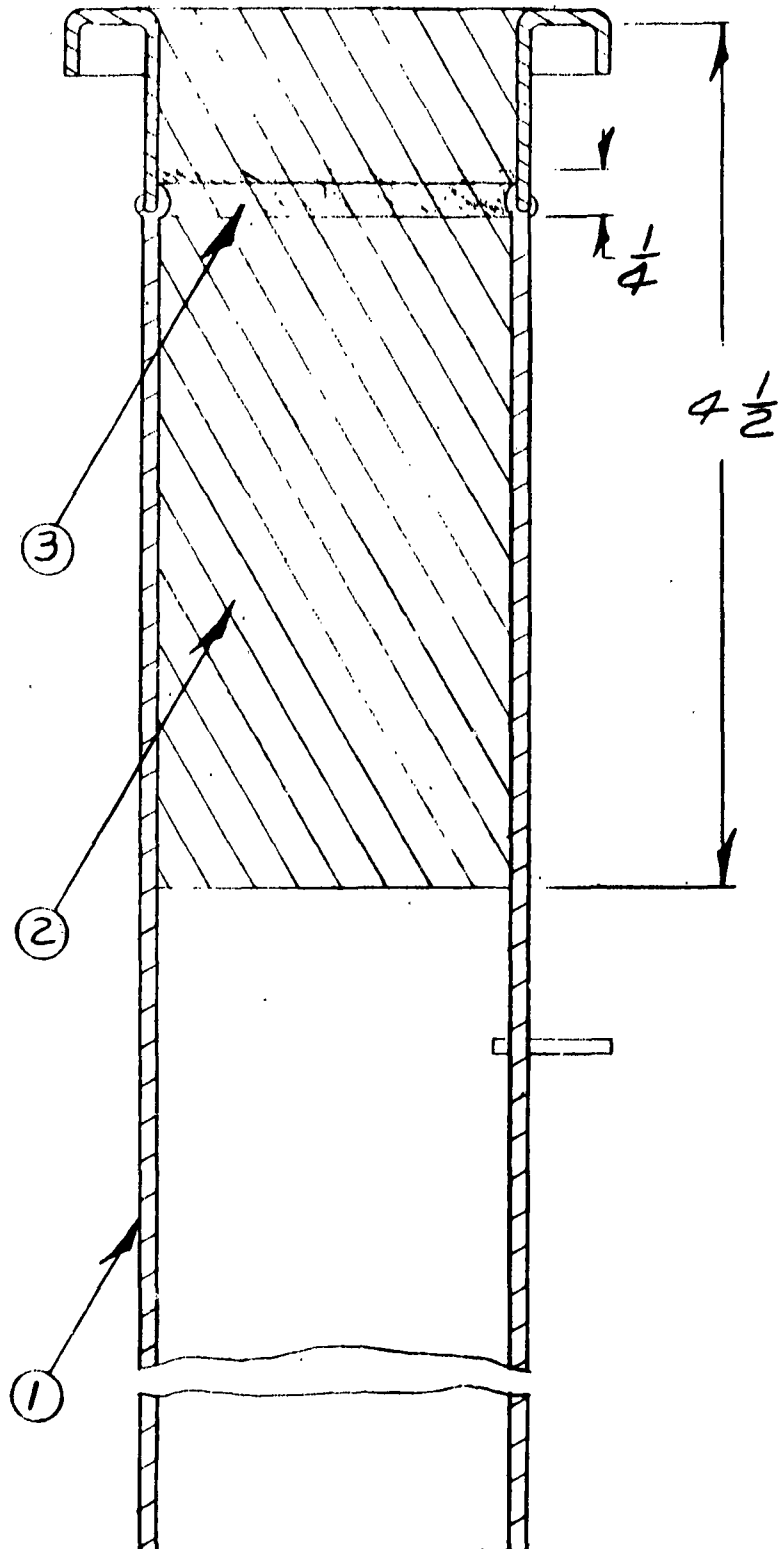
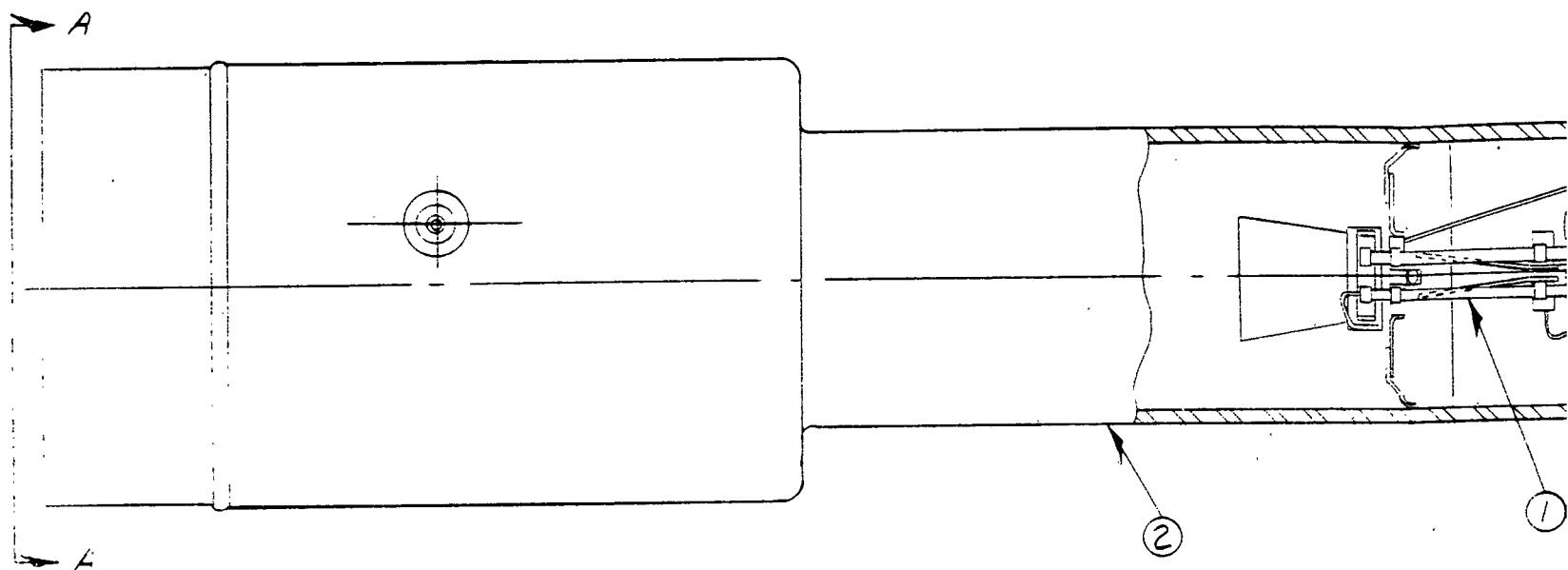


Figure 10. Aluminized Writing-Gun Bulb

1. Reading Gun
2. Aluminized Reading-Gun



NOTE 2

NOTES: 1. ARROW IS DIRECTION OF HORIZONTAL (LOWER) DEFL. PLATES.

2. REF. BUTTON CONNECTED TO ALUMINUM COATING 45° FROM C OF PIN 7 & 19

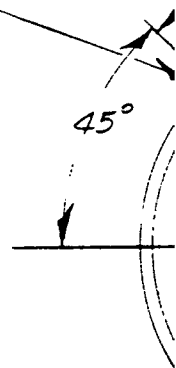


Figure 11. Sealed Reading-Gu



1. Reading Gun
2. Aluminized Reading-Gun Bulb

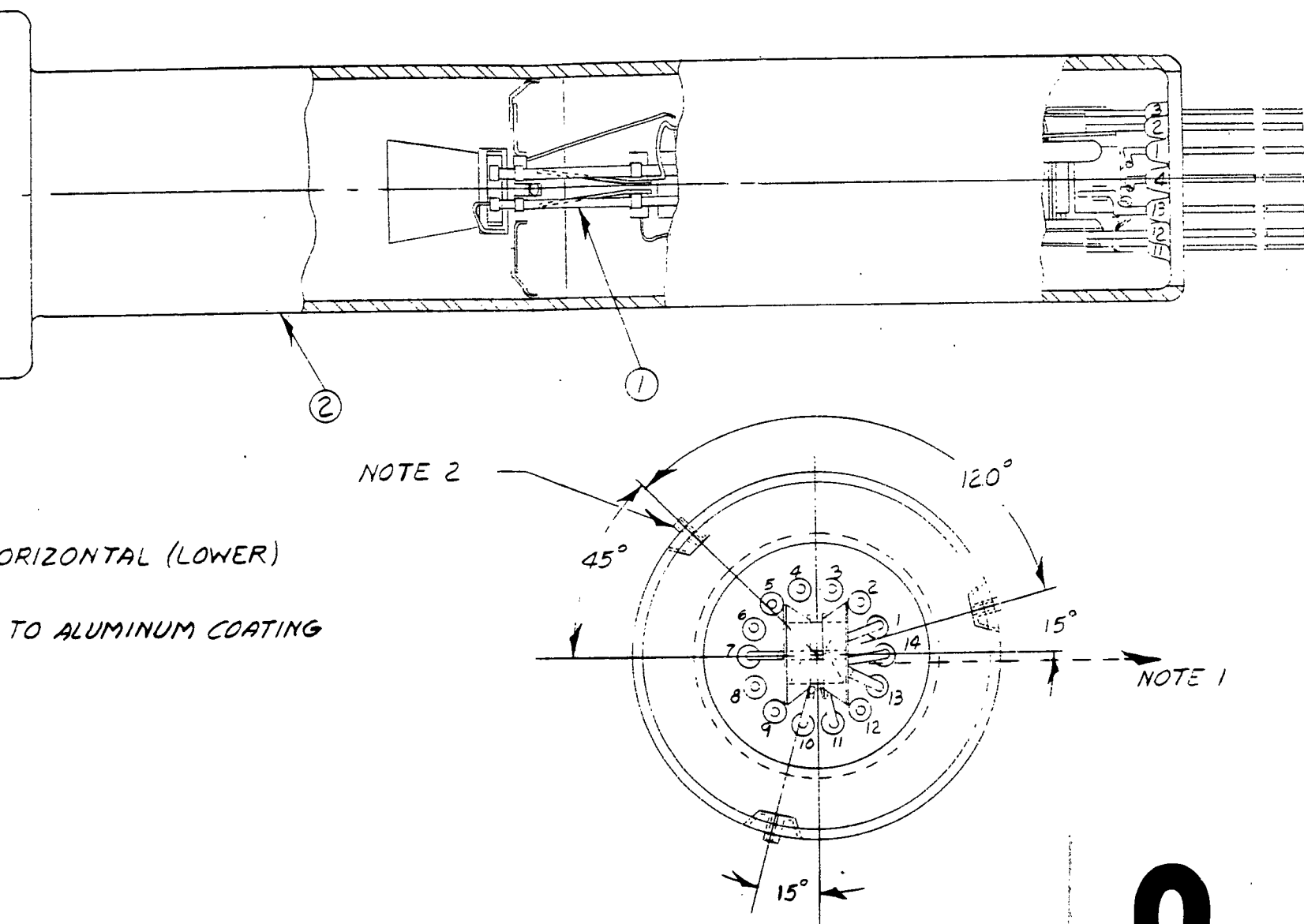
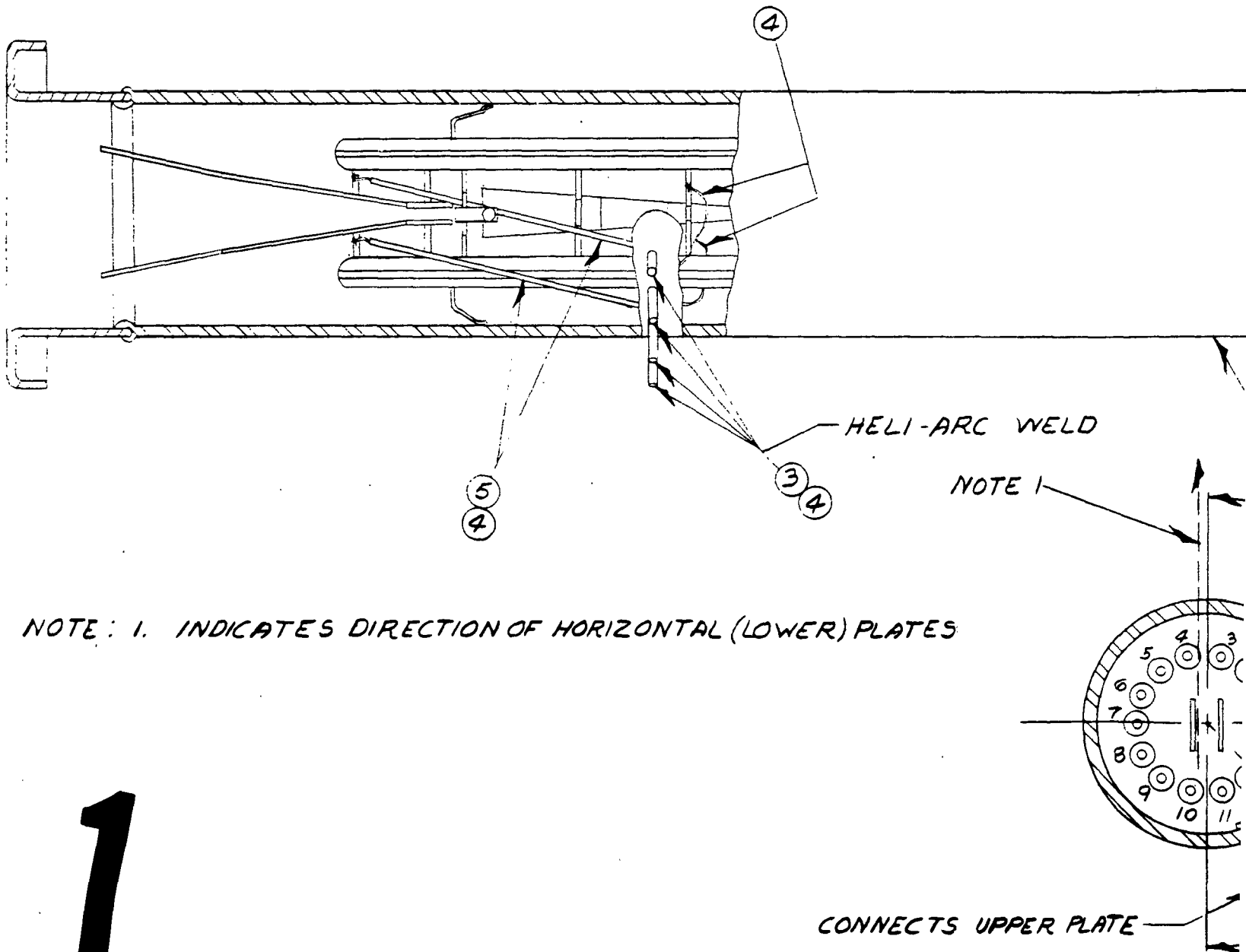


Figure 11. Sealed Reading-Gun Bulb

2

1. Aluminized Writing-Gun
2. Writing Gun
3. Kovar Filler Rod
4. Connector Ribbon
5. Ceramic Insulator Sleeve



1

1. Aluminized Writing-Gun Bulb
2. Writing Gun
3. Kovar Filler Rod
4. Connector Ribbon
5. Ceramic Insulator Sleeve

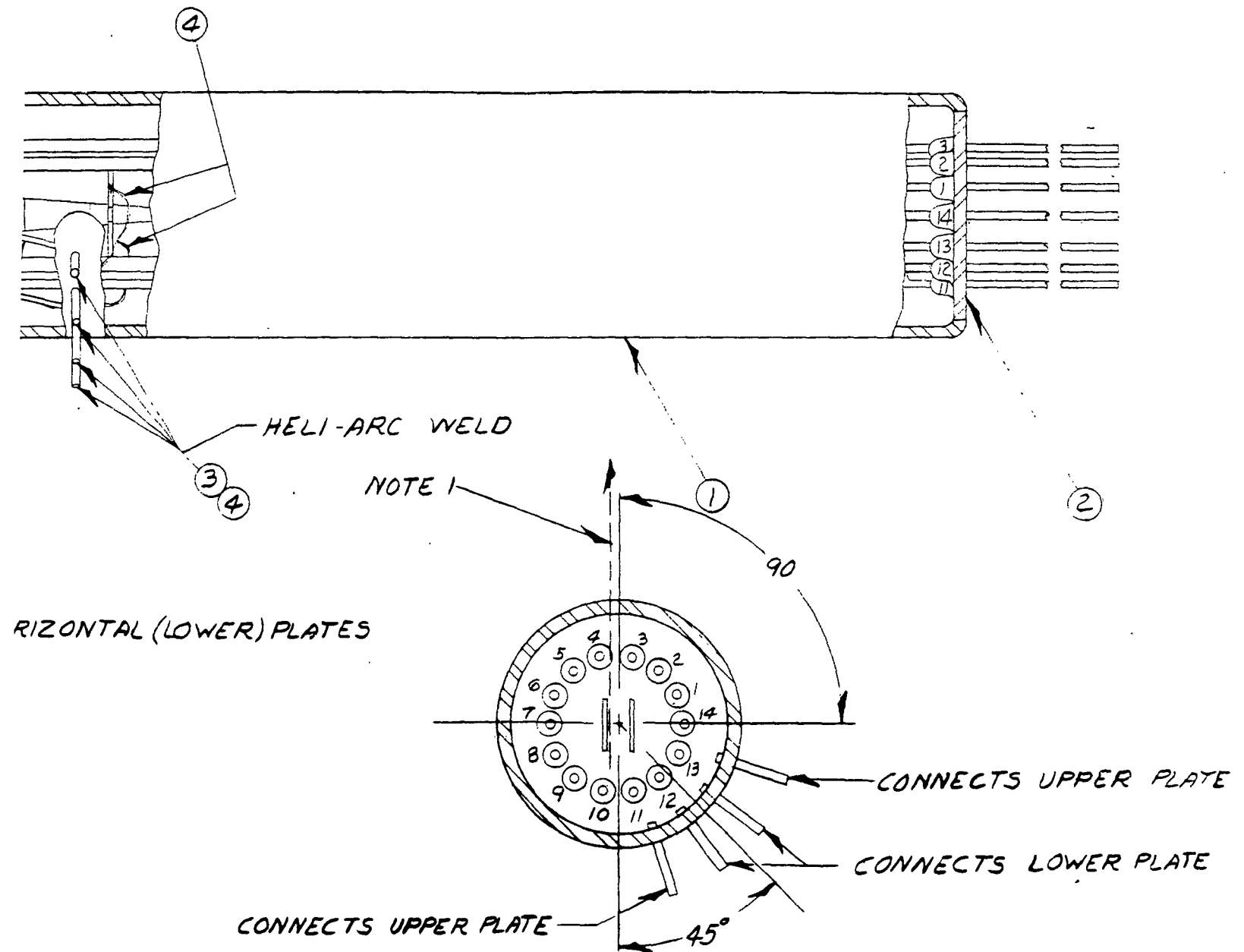


Figure 12. Sealed Writing-Gun Bulb

2

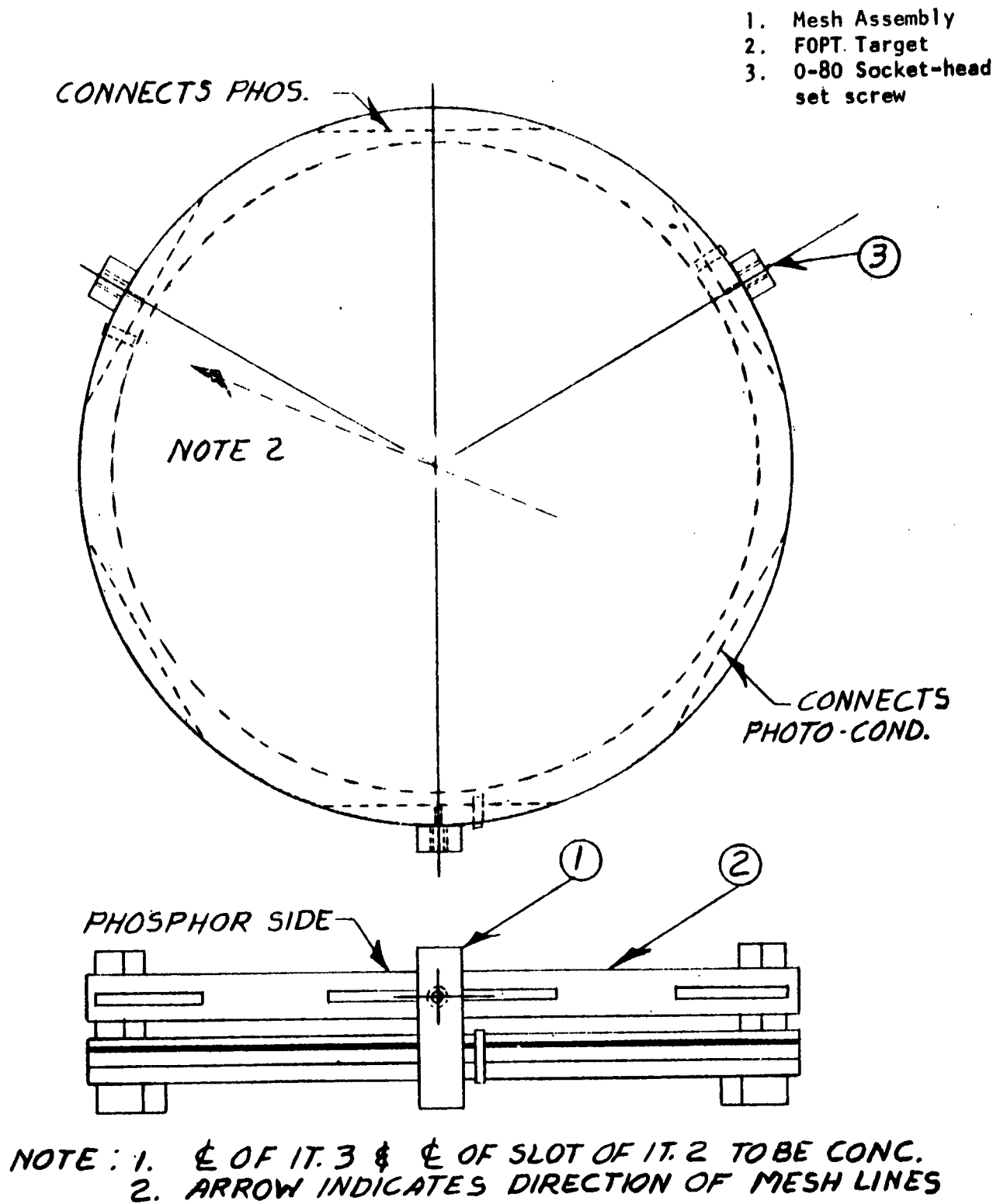


Figure 13. Target-Mesh Assembly

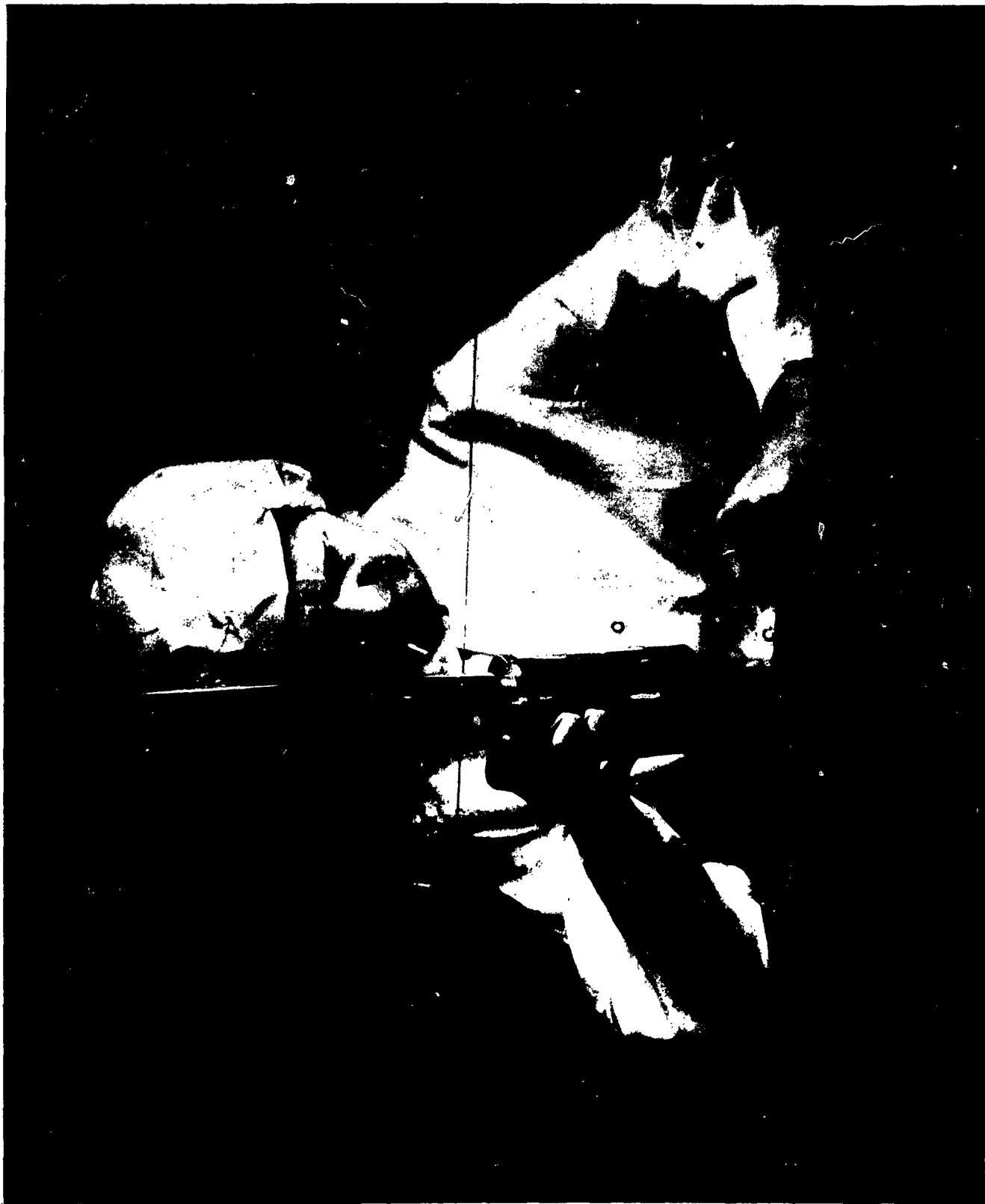
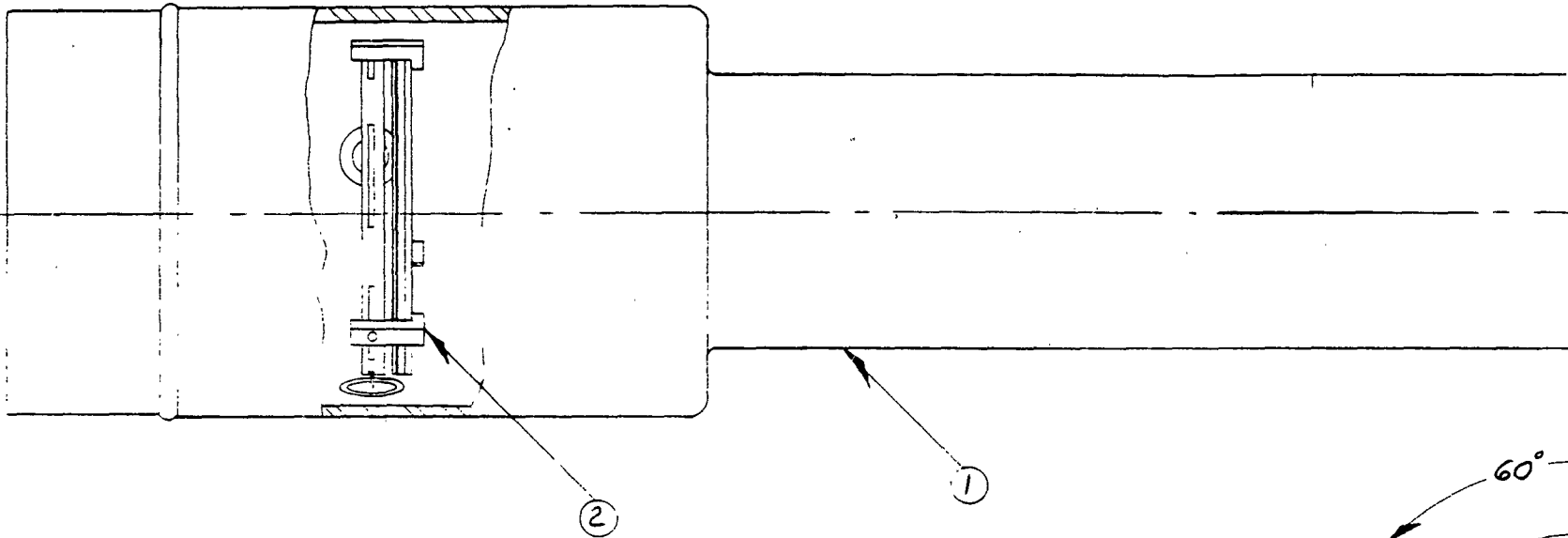


Figure 14. Target-Mesh Assembly Insertion

1. Sealed Reading-Gun Bulb
2. Target-Mesh Assembly
3. Holding Pin



NOTES: 1 ARROW IS DIRECTION OF HORIZONTAL (LOWER.)  
DEFL PLATES

2. INDICATES DIRECTION OF MESH LINES

3. REF. BUTTON (INTERNAL ALUM. CONTACT) CONNECTS  
TO SLOT CONNECTING PHOS OF IT 2

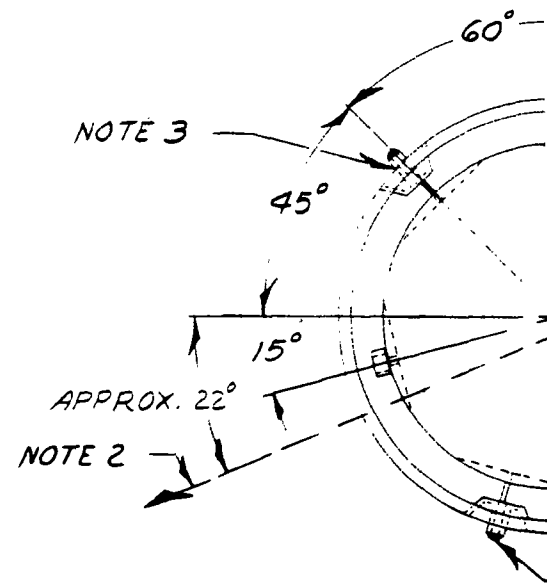


Figure 15. Target-Bulb Assembly

1

1. Sealed Reading-Gun Bulb
2. Target-Mesh Assembly
3. Holding Pin

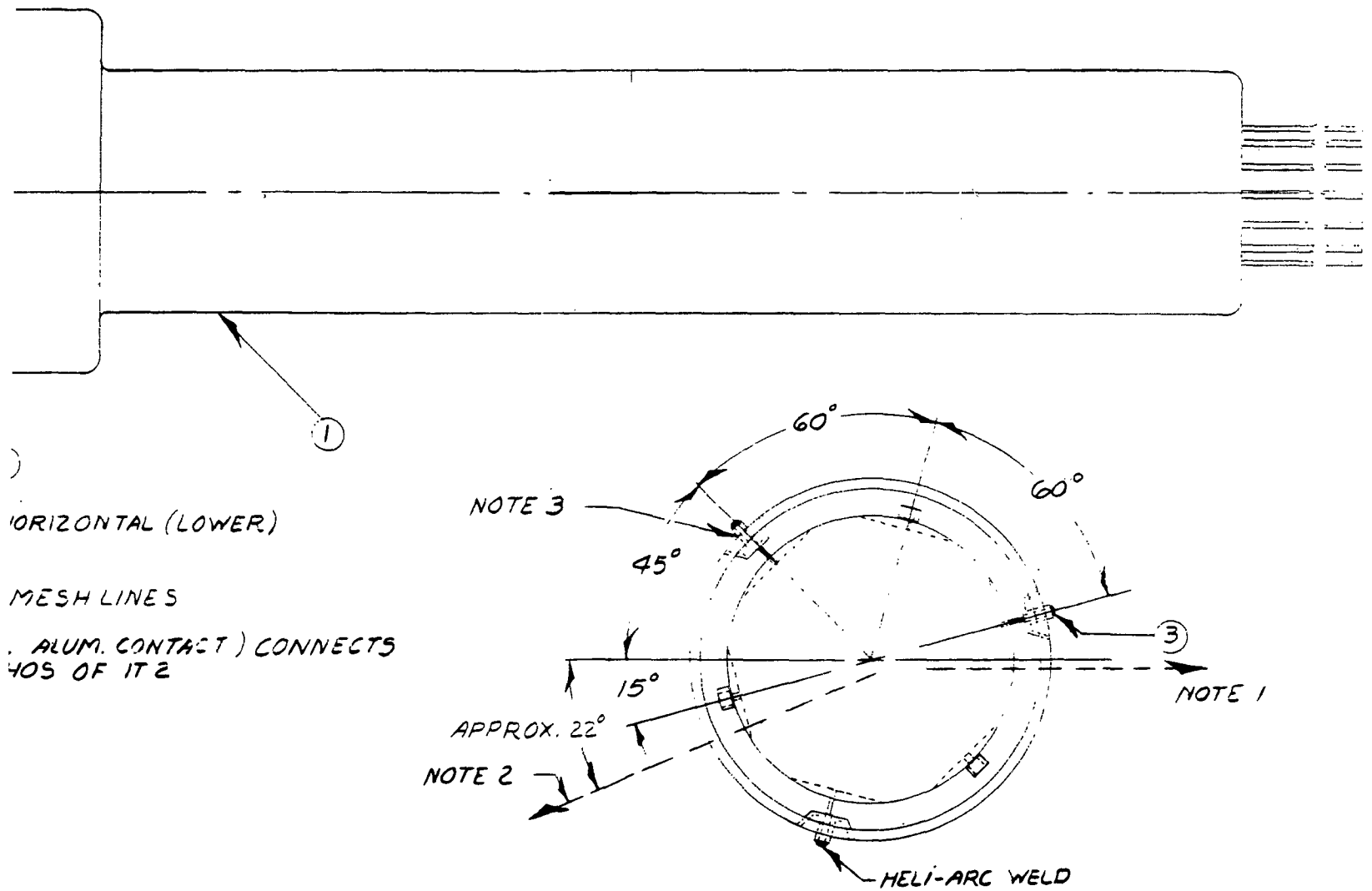


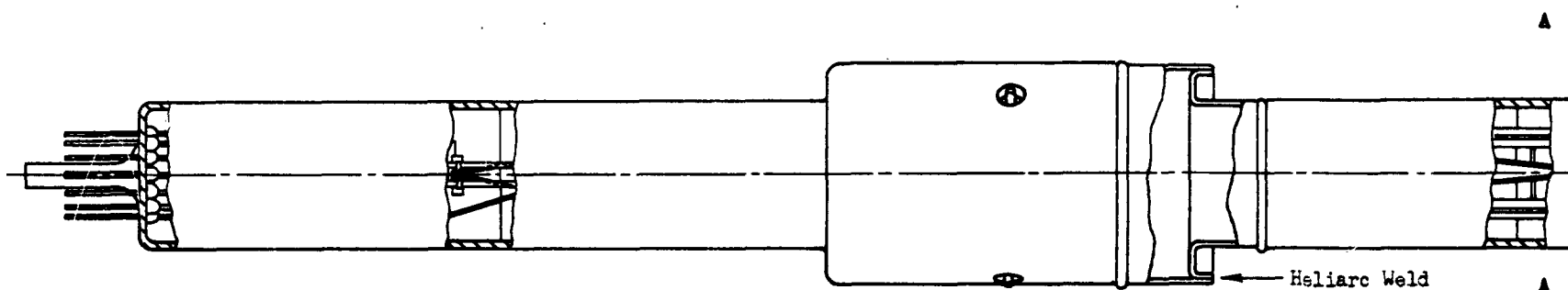
Figure 15. Target-Bulb Assembly

2

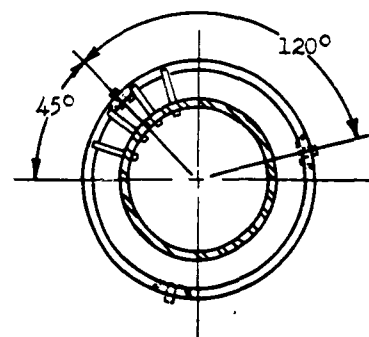


**Figure 16. Making the Final Seam-Weld**





Note: Horizontal Deflection Plates of Reading and Writing Guns are Oriented as Required.



Section A - A

Figure 17. Final Assembly

1

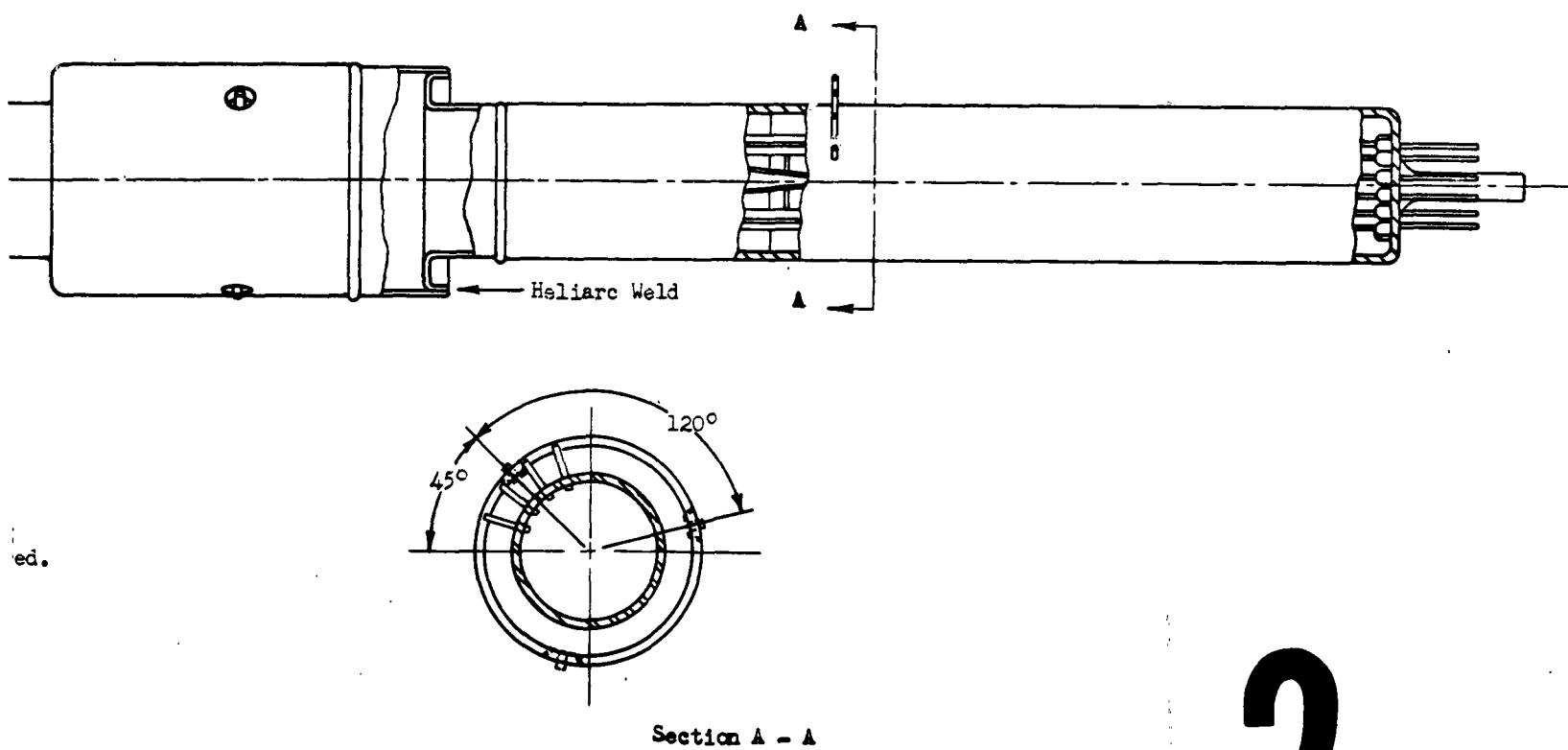


Figure 17. Final Assembly

2

No serious difficulties were encountered in mechanically assembling this tube; including two dummy bulbs, a total of eight of these assemblies have been made.

#### ELECTRON OPTICS

##### WX 4640

The electron optics for the WX 4640 have not been altered during the course of this contract.

##### WX 4821

Two new electrostatically focused and deflected electron guns were developed for the WX 4821. The reading-gun design is a modification of the Westinghouse electrostatic vidicon gun with an elongated limiting-aperture-to-focus-lens distance and enlarged deflection plates. The object distance increase provides a more favorable spot magnification in this tube, and the larger deflection plates are required to accommodate the increased scan area. During the course of the contract, a bead-supported deflectron made by Sawyer Associates was evaluated and found to be fragile, costly, and required greater drive voltages than deflection plates.

Figure 18 is a photograph showing a technician welding the stem to a reading gun in the clean room. Figure 19 is a drawing of the mounted gun.

The writing-gun design was based on the 5BH type and required a change in the focus-lens and deflection plates to operate properly. The triode of the gun is similar to the one used in the writing gun of the WX 4640.

Figure 20 is a photograph of the deflection plate assembly being held in a beading fixture during the beading operation. Once beaded, this assembly is welded to the triode section and stemmed, to result in the complete mount shown in Figure 21.

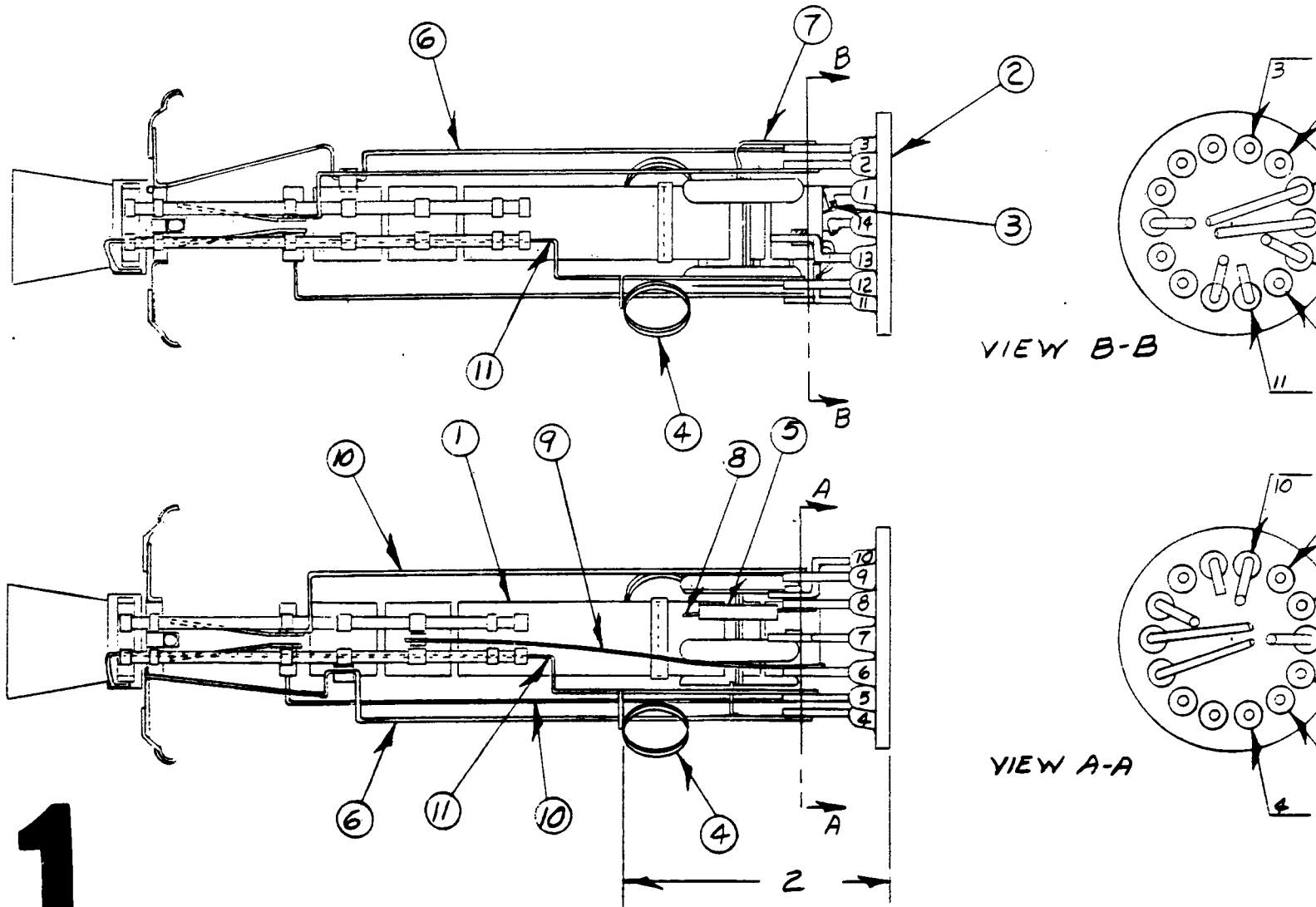
Performance data on both of these guns are given in the Quarterly Reports.



Figure 18. Stemming the Reading Gun

1. Assembled Gun
2. Stem
3. Heater
4. Getter
5. Identification Number
6. - 11. Connecting Wires

All dimensions in inches

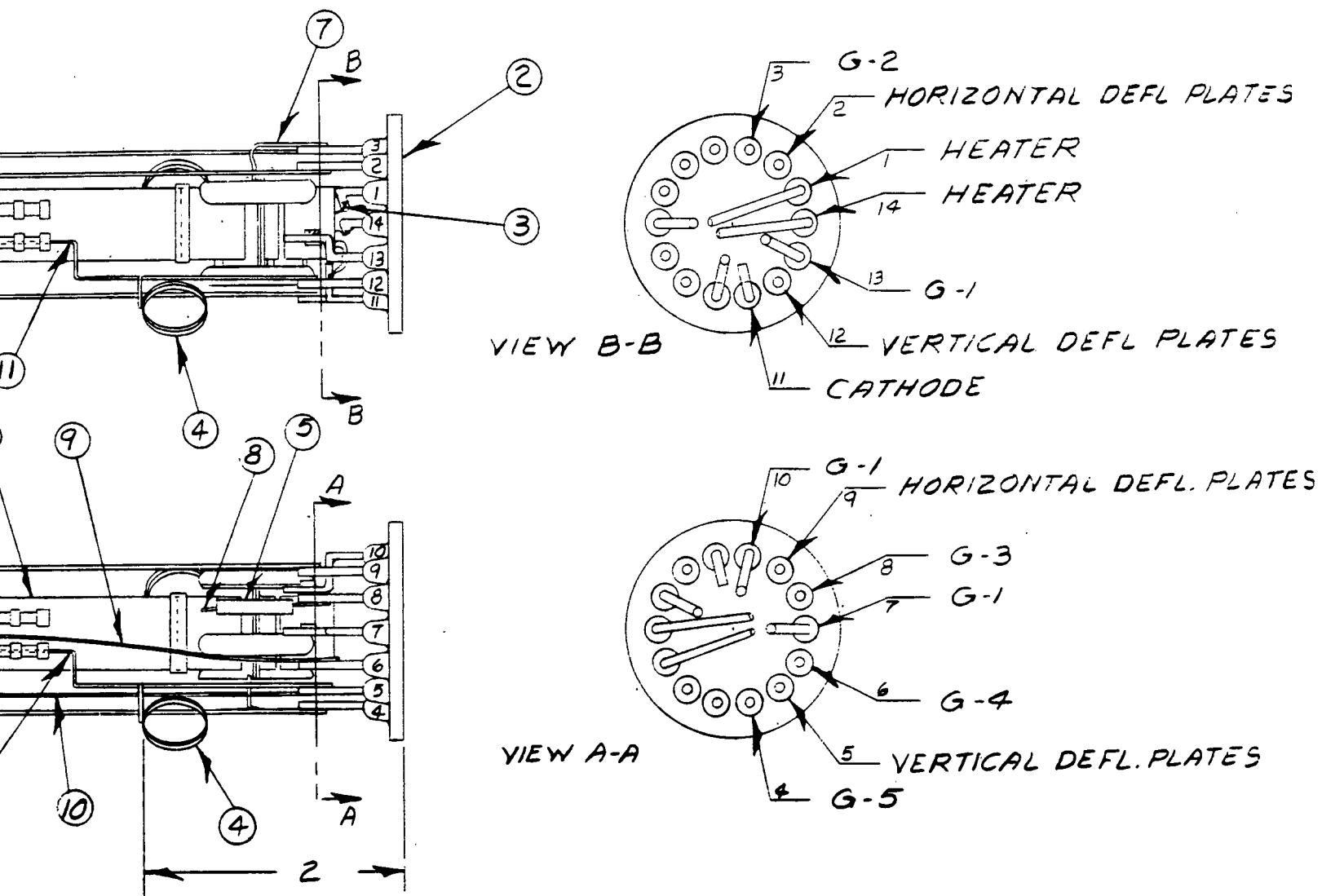


NOTE: 1. SPOT WELD ALL ITEMS

Figure 19. Mounted Reading Gun

1. Assembled Gun
2. Stem
3. Heater
4. Getter
5. Identification Number
6. - 11. Connecting Wires

All dimensions in inches



NOTE: 1. SPOT WELD ALL ITEMS

Figure 19. Mounted Reading Gun

2

**Figure 20. Dip-Beading the Deflection Plate Assembly**



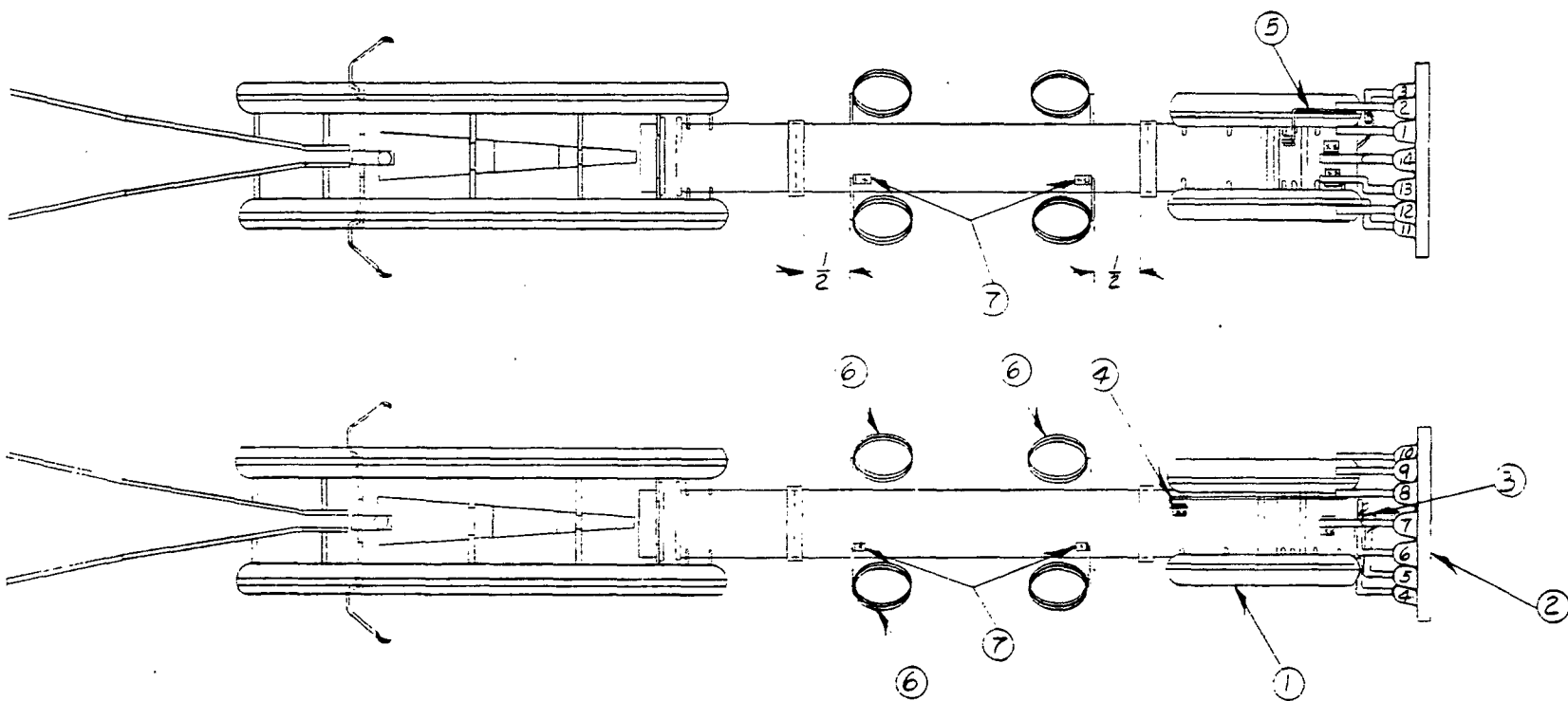
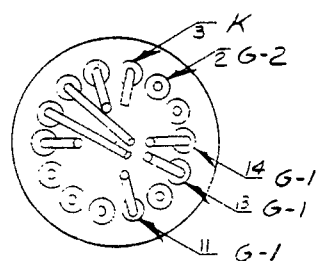
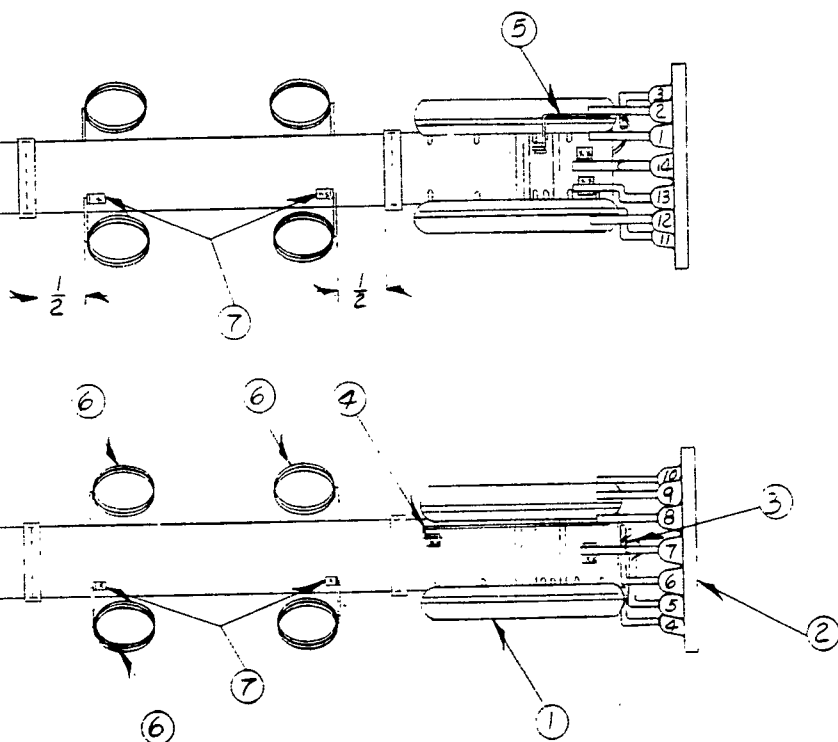


Figure 21. Mounted Writing Gun

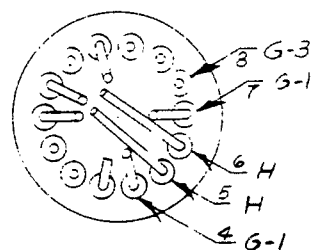
1





1. Assembled Gun
2. Stem
3. Heater
4. and 5. Connecting wires
6. Getter
7. "L" Support

All dimensions in inches



NOTE: 1. SPOT WELD ALL ITEMS

2.  $\frac{1}{2}$  OF IT. GET TO BE CONC. WITH  $\frac{1}{2}$  OF LEAD 5 & 12

Mounted Writing Gun

2

#### Low-Power Heaters

In connection with the electron guns an effort was made to incorporate a 0.2 watt Sylvania heater-cathode assembly in the WX 4640. The low-power emitter was initially evaluated in a vidicon and a writing-gun simulator tube WX 30210. Both of these devices worked satisfactorily; however, when the low-power assembly was incorporated in complete WX 4640's emission was very low in tube Nr. 29, and Nr. 32 developed a cathode-to-grid-1 hot-short in the writing gun during processing.

Before these lower-power assemblies can be recommended for use in the scan-converter, the processing schedules and assembly techniques will have to be studied.

#### VACUUM PROCESSING

##### WX 4640

No changes have been made during this contract in the methods used to process the WX 4640.

##### WX 4821

After the first two WX 4821's were constructed and exhausted, using a schedule similar to that used for the WX 4640, it became apparent that the pre-exhaust vacuum-baking of the reading and writing bulb assemblies was not, by itself, sufficient to establish a good vacuum environment in the finished tube.

As a result, a special tube Nr. 1002 was constructed, which included a thermocouple that was in contact with a 7056-glass target-replica. With this tube a schedule was derived whereby both of the electron guns in the tube can be radio-frequency (RF) heated without raising the temperature of the target above 40°C.

The schedule that resulted from these experiments consists of applying a pulse of RF energy to a portion of a gun and then allowing it to cool until the target temperature drops to approximately 28°C; pulsing again, etc. The RF pulses average 10 minutes in duration and the cooling

periods 30 minutes, and the entire process for the tube requires about 8 hours.

In addition to the pulsed processing, a one-liter-per-second ion-pump was also attached to one end of the tube (Figure 22 is a photograph of a WX 4821 on exhaust with the ion-pump and its power supply on the left side.) The pump is attached to the tube via a bellows to receive the mechanical stress on the stem tubulation. The ion-pump is not only used during processing on the exhaust cart but also while the tube is being initially tested, so that any gases evolved from either the target or other electron-bombed areas can be pumped out. After initial testing, this appendage pump is tipped off. On the three WX 4821's where the appendage pump has been used, it has been tipped off at between 1 and  $5 \times 10^{-7}$  mm of mercury pressure.

The combination of the appendage pump and the pulsed RF outgassing has provided more stable pressure and emission in the tube. However, since only three tubes were processed in this manner, it is difficult to make a complete evaluation of the technique.

#### TUBES CONSTRUCTED

A total of 51 tubes was constructed during the course of this contract. Table I indicates the numbers and types of tubes constructed each quarterly period. Details of the tubes made during the first four quarterly periods are contained in the Quarterly Reports, and details of tubes built during the last quarter are listed in Table II with a description of each and its operating characteristics.

Tubes Nr. 8, 11, 30, and 31 were delivered to USAEL during the course of the contract.

Display models of the WX 4821 and WX 4640, which demonstrate in an exploded mounting the construction features of the final model tubes, were also delivered. Figures 23 and 24 are photographs of the display boards.



**Figure 22. WX 4821 on Exhaust Position**

TABLE I

## TUBES CONSTRUCTED

Quarterly Period	WX4640	WX4821	Reading Gun Simulator (WX4640)	Writing Gun Simulator (WX4640)	Reading Gun Simulator (WX4821)	Writing Gun Simulator (WX4821)	Special Test Tubes	Tubes for Quarter
1	5	--	--	1	--	--	--	6
2	7	--	--	--	1	1	--	9
3	8	--	--	--	1	1	--	10
4	6	1	--	--	3	1	3	14
5	5	5	1	1	--	--	--	12
Total	31	6	1	2	5	3	3	51 Grand Total

TABLE II

TUBES CONSTRUCTED DURING THE 5th QUARTER

<u>Tube No.</u>	<u>Seal-in Date</u>	<u>Photoconductor Material</u>	<u>Phosphor</u>	<u>Operational Characteristics</u>	<u>or</u>	<u>Reason for Failure</u>
28	28 Jan 64	#6	P-20			Low Target Resistivity
29	5 Feb 64	#6	P-20			.2 watt Heaters No emission
30	13 Feb 64	--	P-20	Writing Gun Simulator Normal Operation		
31	18 Feb 64	#6	P-20	High Dark Current Test of 1.0 NA Fiber-Optics		
32	28 Feb 64	#6	P-20			Writing Gun G <sub>1</sub> -K Hot Short (.2 watt heater)
33	21 Feb 64	--	P-20	Reading Gun Simulator Normal Operation		
34	30 Mar 64	#6	P-20	Zone defects in Fiber-Optics (lot of discs rejected)		
1001	15 Jan 64	#8	P-20			Tube Gassy. Target did not charge properly.
1002	20 Feb 64	--	P-20	Both sides of target simulator Internal thermocouple use to determine processing schedule		
1003	11 Mar 64	#6	P-20	Guns operated properly		Lost target contact
1004	30 Apr 64	#6	P-20	Insufficient beam to charge target		Poor focus of write gun.
1005	5 May 64	#6	P-20			Insufficient emission both cathodes

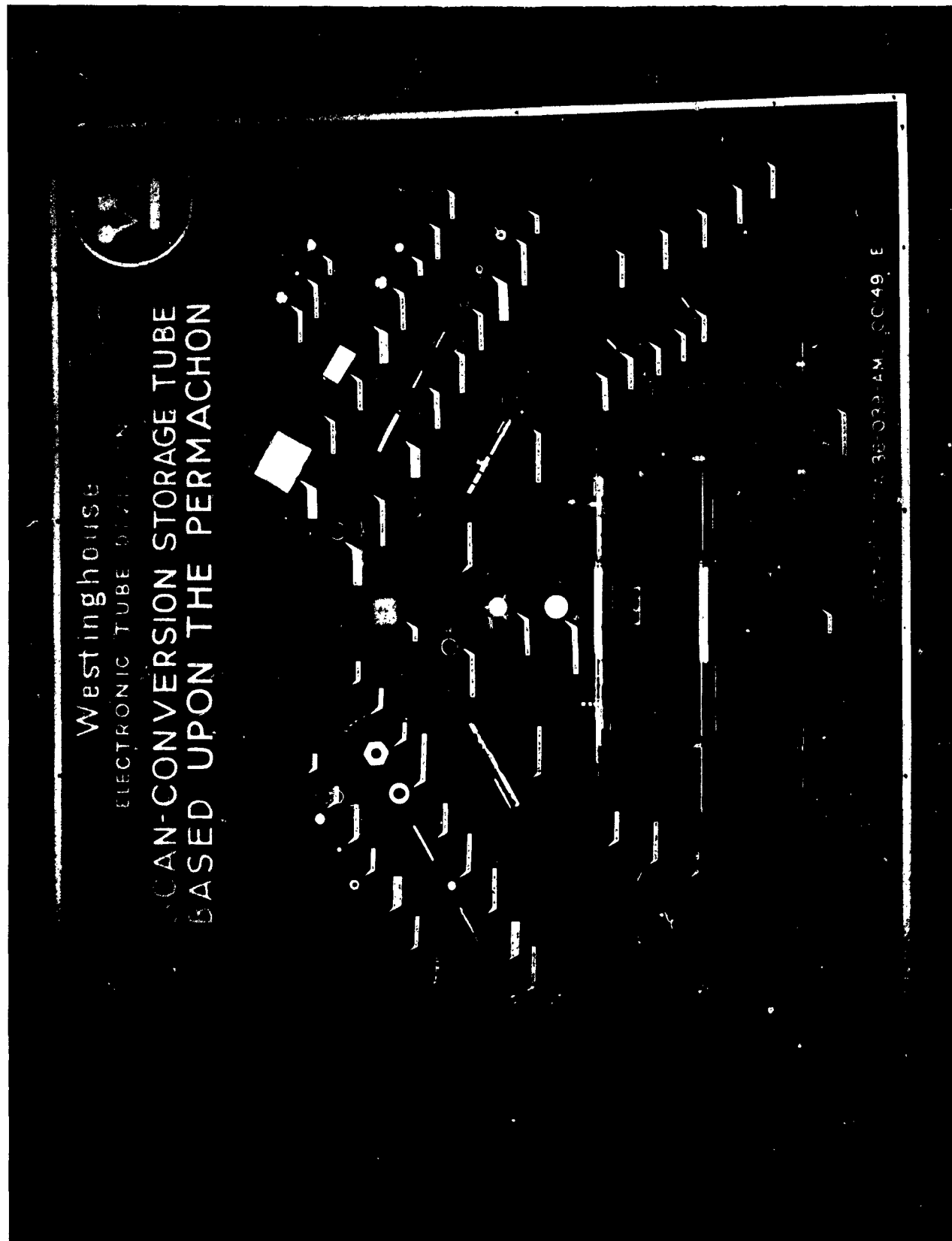


Figure 23. WX 4640 Display Board

Westinghouse  
ELECTRONIC TUBE DIV.

# SCAN-CONVERSION STORAGE TUBE BASED UPON THE PERMACHON

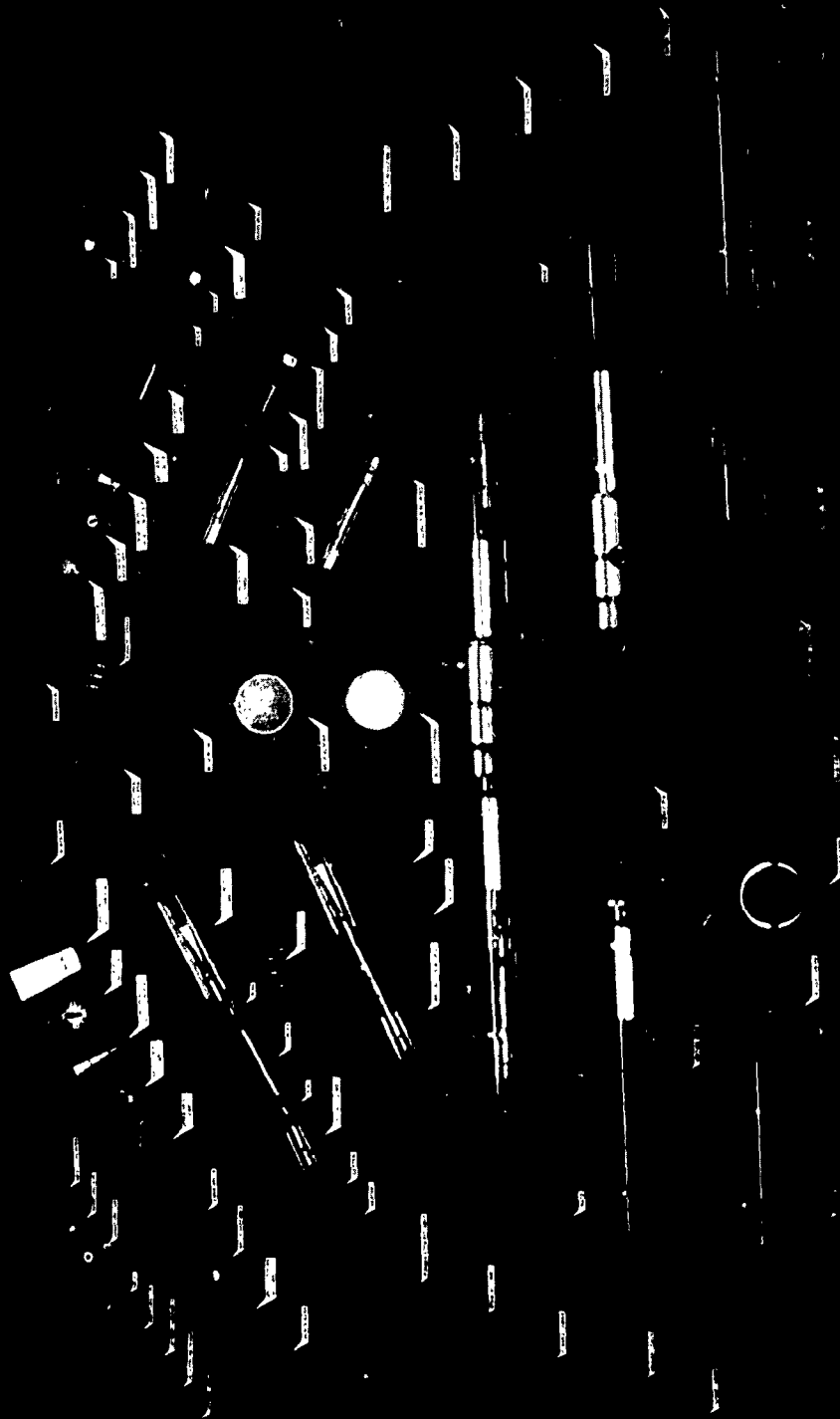


Figure 24. WX 4821 Display Board



## TEST EQUIPMENT

Figure 25 is a photograph of the test-set used to evaluate both types of scan-conversion tubes. The test equipment is comprised of the basic power supplies, drive circuitry, and monitors required to operate both types of tubes, as well as five input signal sources. Only the sweep synchronizing signals are obtained from outside the test set.

During this contract period the additional equipment required to operate the WX 4821 was added to the test set, along with a solid-state grey-scale generator.

The functions of the test-set components are described in detail in the Final Report of the previous scan-converter contract DA-36-039-sc-85051.

## OPERATING CHARACTERISTICS

Many varied types of tests have been performed with scan-converters during the course of this development program, and the results of most of these tests were described in detail in the Quarterly Reports and are referenced below with a short summary.

<u>Characteristic</u>	<u>Typical Operation</u>	<u>Report Nr.</u>	<u>Page</u>
Storage	30 minutes - down to half amplitude in 5 to 10 min.	10	40
Unenhanced Erasure	Fully erased in 10 seconds or less.	10	44
Enhanced Erasure	Fully erased in 5 TV fields or less.	12	18
Writing	About 1 second required to write at TV rates.	11	14
Dark Current	Rises with storage time and brings blacks to white.	10	41-42

In addition to these characteristics, data were taken during the last Quarterly Period on aperture response, charge-down after erasure, and flood-beam holding.

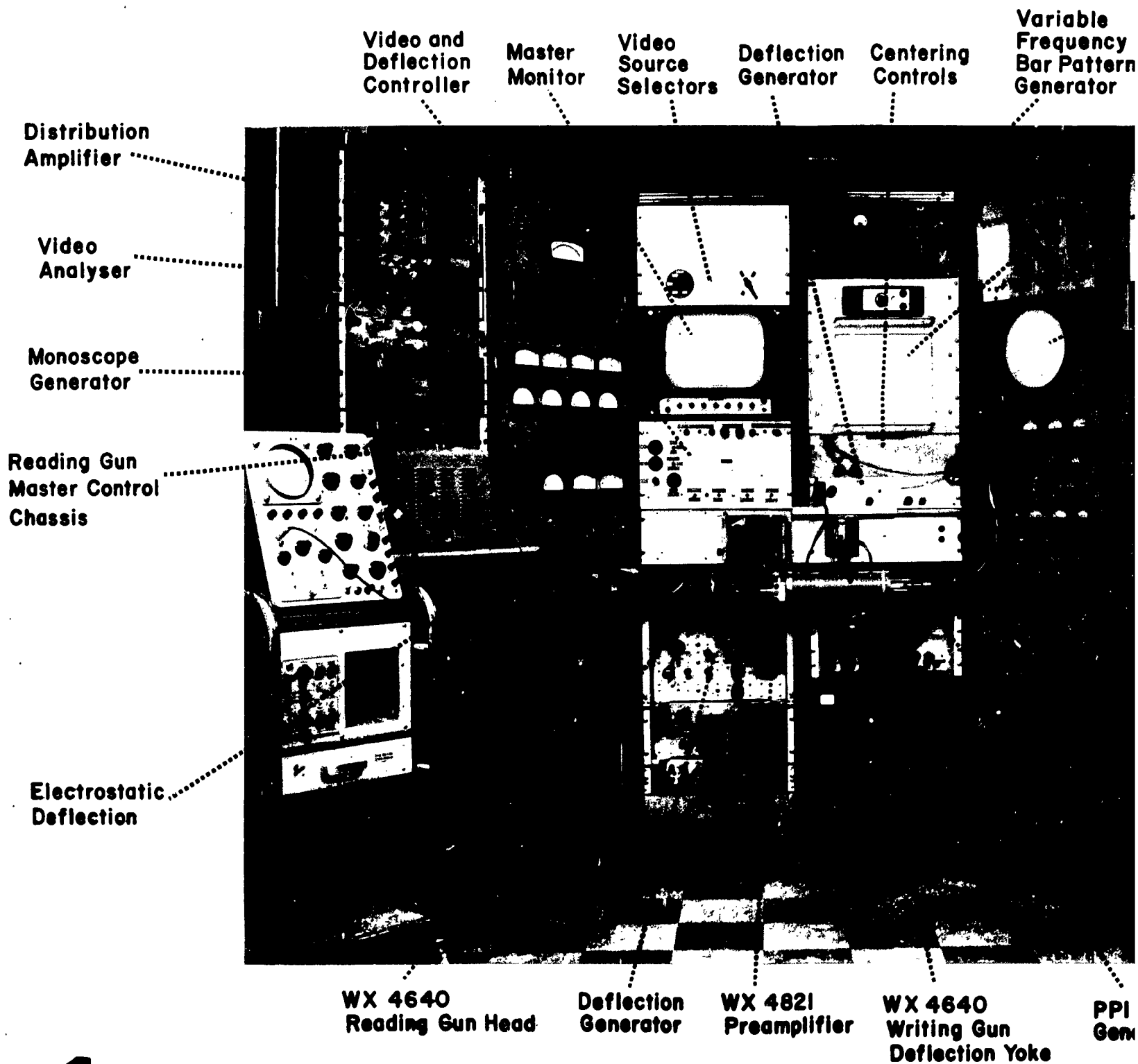
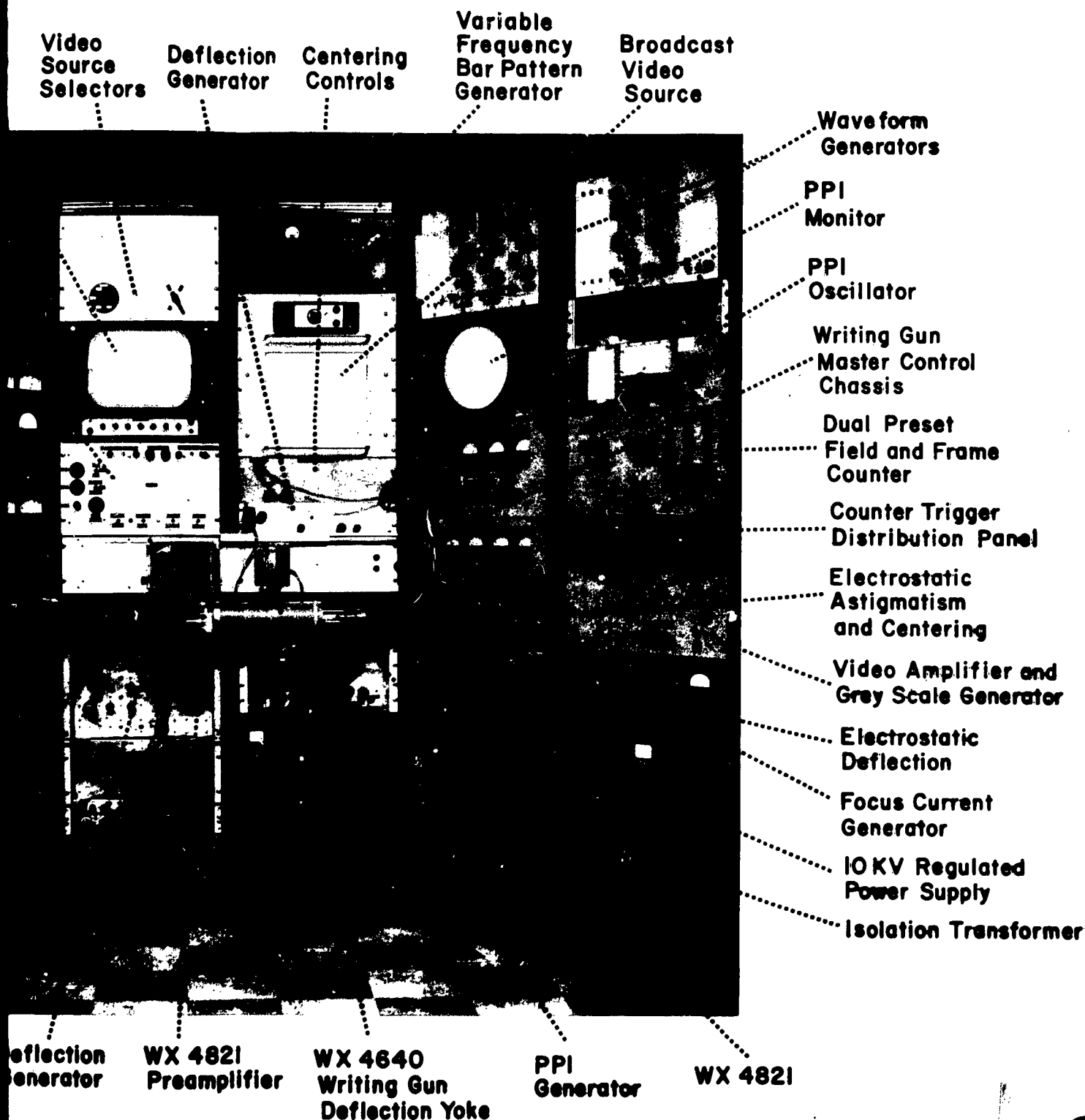


Figure 25. Scan-Converter Testing Equipment



## Scan-Converter Testing Equipment

### Aperture Response

In this tube aperture response is a measure of the overall resolving capability of the tube, including its associated equipment. The sine-wave aperture-response of 5 WX 4640's was measured by writing a raster of vertical bars generated from a Foto-Video Model V333A TV and radar keyed-video-signal generator onto the target. Once stored, the bars are read out with a standard  $3/8 \times 1/2$ -inch raster, and the video signal is displayed on a line-selector oscilloscope. The peak-to-peak amplitude of the output signal is measured directly from the display and plotted as response factor for different numbers of lines stored. As plotted in Figure 26, the data are normalized to TV-lines per inch, so that the number of lines per diameter or other dimension can be obtained by making a simple calculation.

It can be seen from the curves that the type of fiber-optics disc does make a significant difference in the resolution of the tube, since each disc had a fiber pitch of 7 microns. Unfortunately, the dark-EMA-type fiber-optics has the best resolution but introduces a coherent noise pattern in the output signal.

### Charge-Down

Charge-down after erasure is the process whereby the front surface of the photoconductor is returned from signal-electrode potential to reading-gun-cathode potential to re-establish the required potential gradient across the photoconductor. The charge-down time is a function of the photoconductor capacitance, the signal-electrode-to-reading-gun-cathode voltage, and the reading-beam current. Figures 27 and 28 are the charge-down characteristics of tubes 3 and 19, respectively. Tube 3 has a higher beam-current capability than 19; however, the normal charge-down time is similar, since the tubes are generally operated with a beam current of between 2 and 4 microamperes.

Figures 29 through 34 show the particular oscilloscope presentation of the charge-down signals from tube 3 with a target voltage of 5

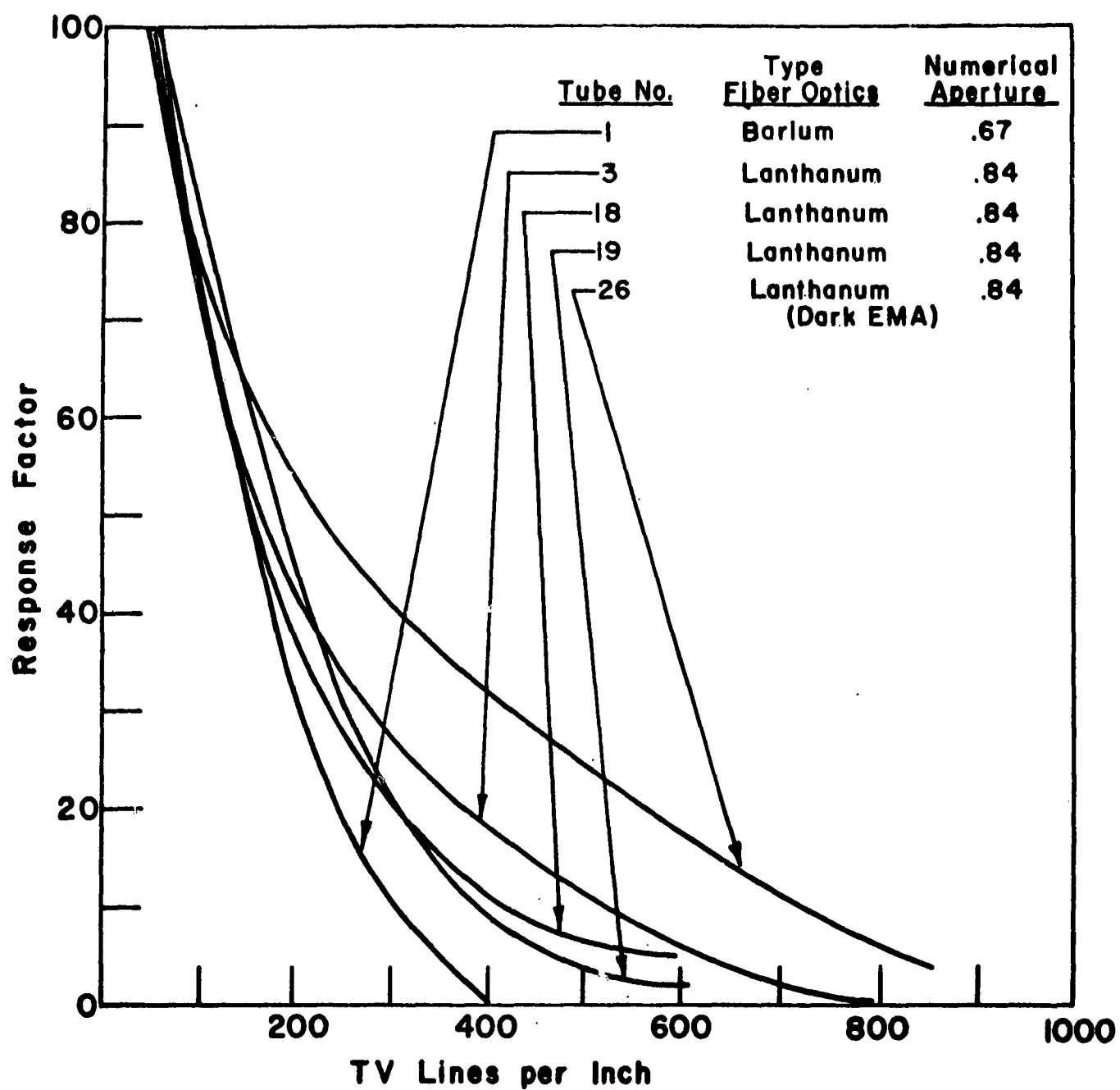


Figure 26. WX 4640 Aperture-Response

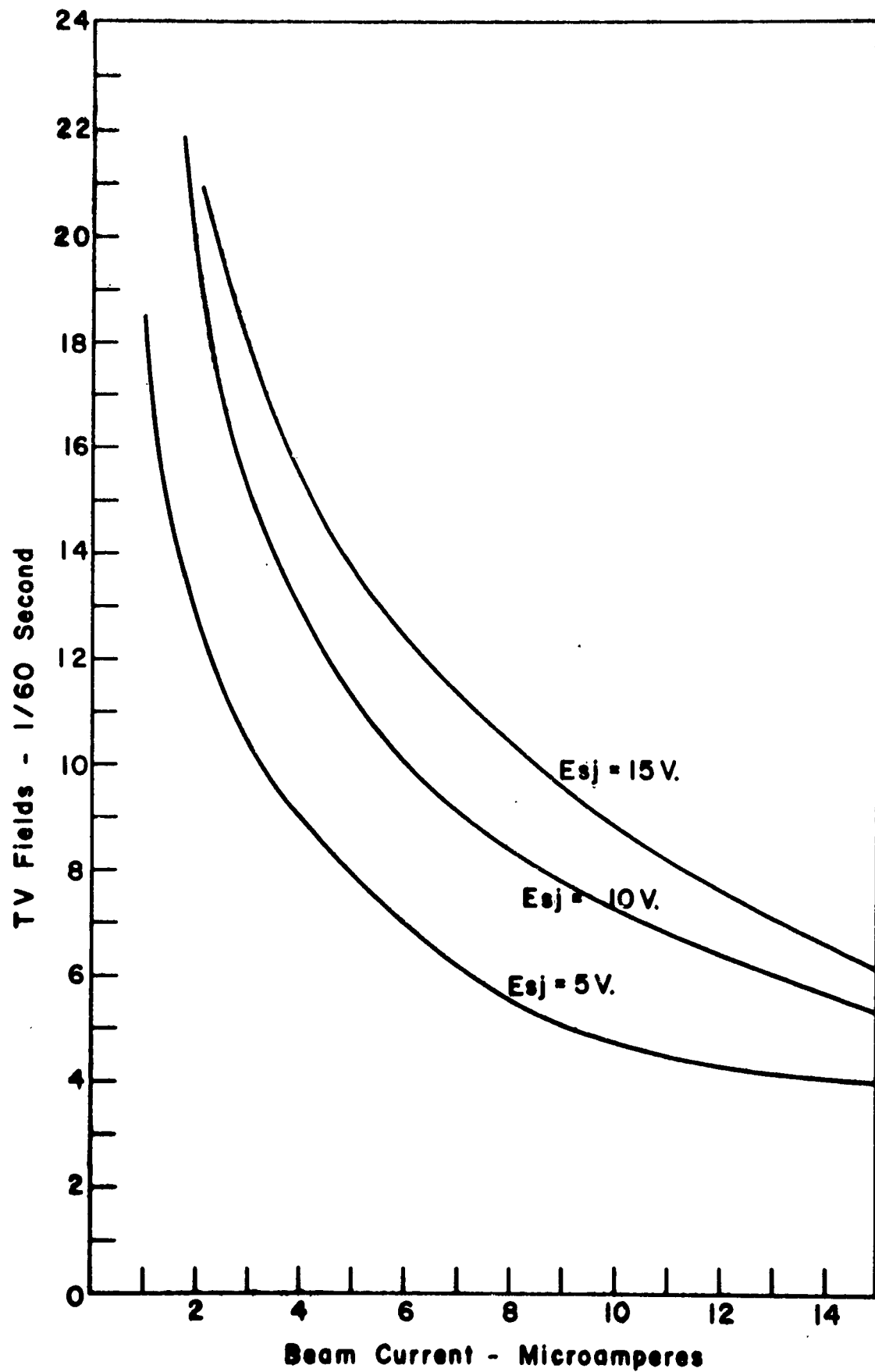


Figure 27. Charge-down Characteristics, Tube No. 3

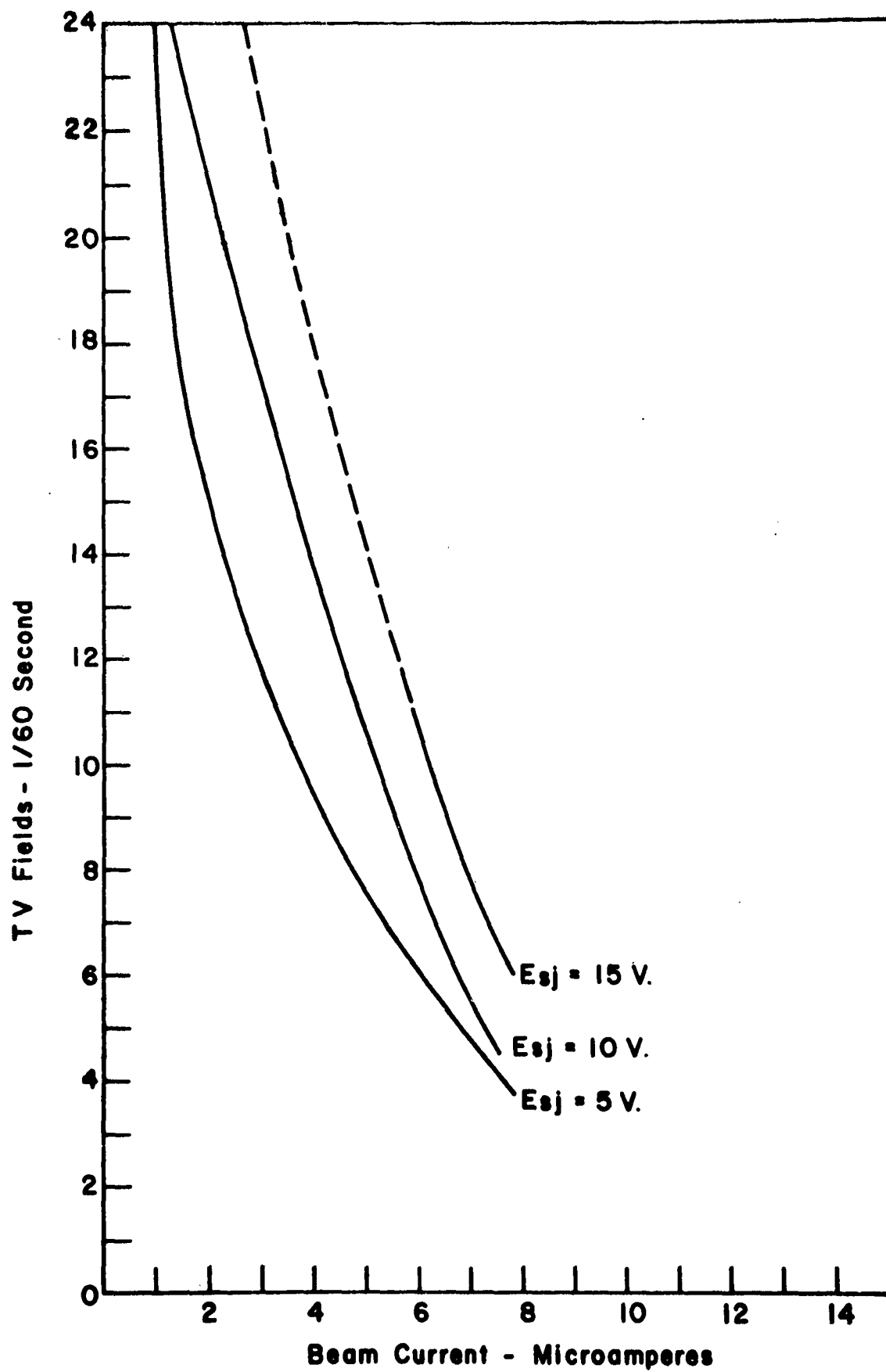


Figure 28. Charge-down Characteristics, Tube No. 19

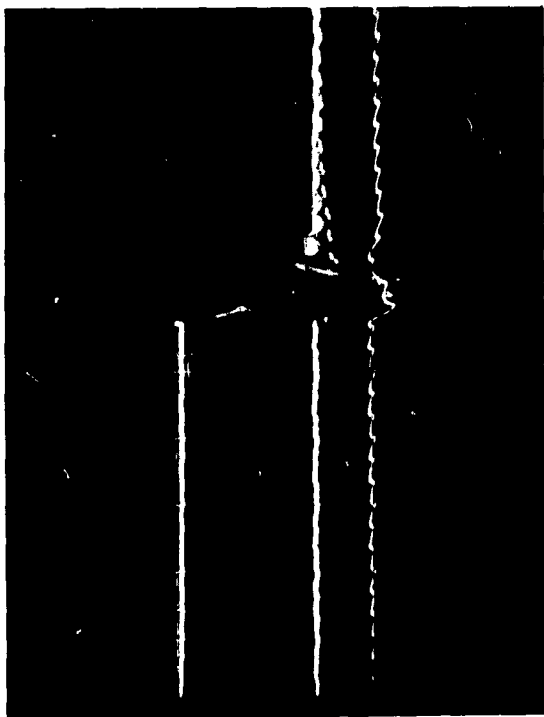


Figure 29.  $E_{g1}$  0  $I_B$  15µa

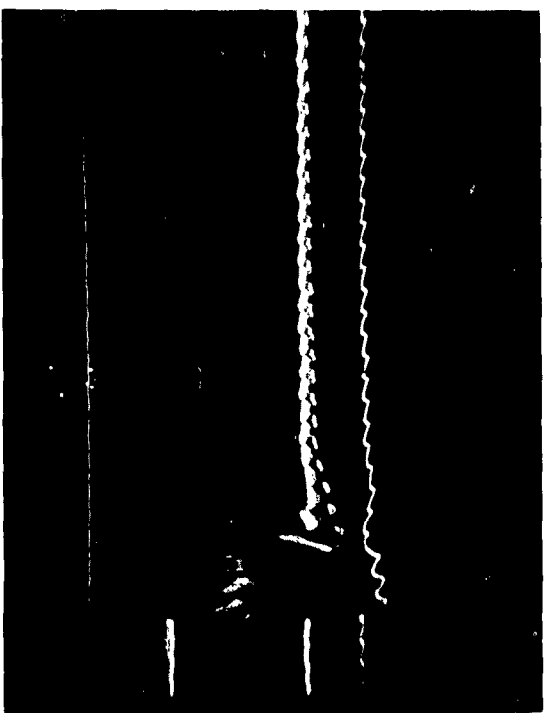


Figure 30.  $E_{g1}$  -10  $I_B$  14µa

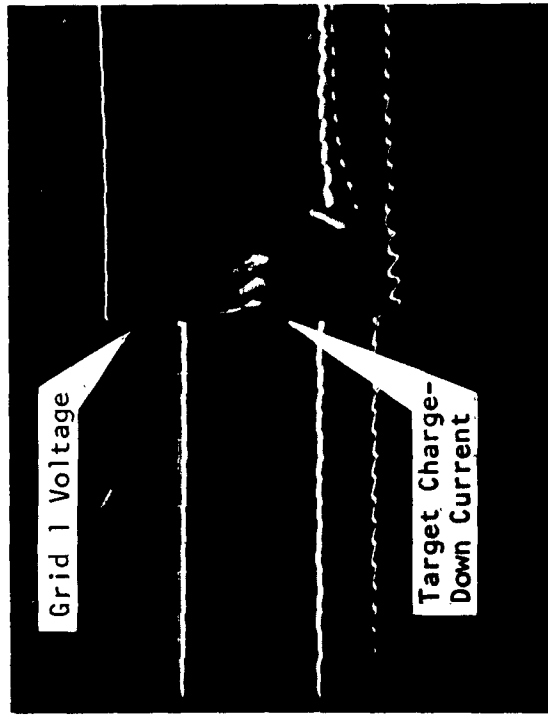


Figure 31.  $E_{g1}$  -20  $I_B$  13.6 µa

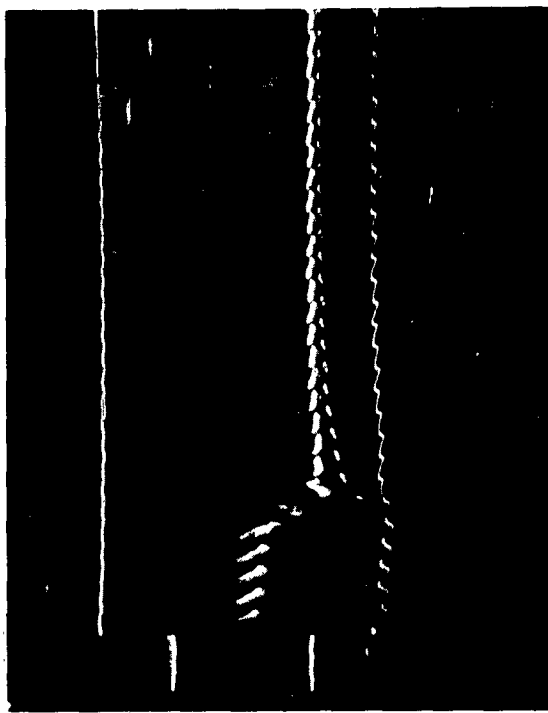


Figure 32.  $E_{g1}$  -30  $I_B$  5.8 µa



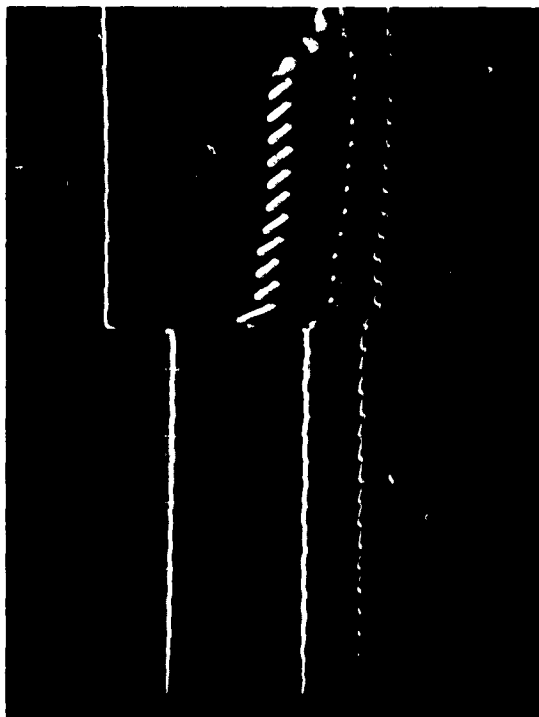


Figure 33.  $E_{g1}$  -40  $I_B$  2 $\mu$ a

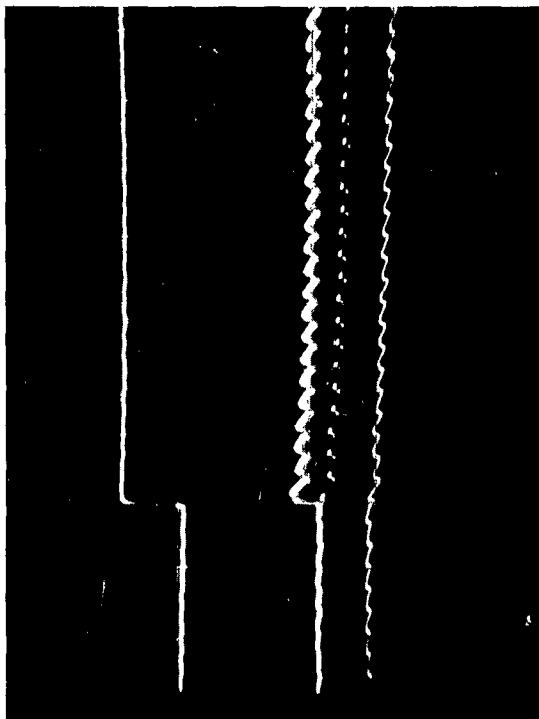


Figure 34.  $E_{g1}$  -50  $I_B$  1.1  $\mu$ a

**Tube No. 3 Charge - Down Signals ( $E_{s1}$  5V)**

volts; a similar series of data were taken for each of the charge-down curves plotted. In each photograph the top trace shows the grid 1 voltage change from the cutoff state (-150 volts) to the on value. As the on-voltage decreases, the beam current decreases and the number of fields required to charge-down the target increases.

These charge-down data indicate that if it is required to charge-down the target in a minimum time, the grid 1 bias should be lowered to a value near zero volts during the charge-down cycle.

#### Electron Flood Storage

The ability of a flood of electrons to maintain storage in a Permachon photoconductor was investigated by removing both the scanning and focusing fields of the reading gun in a WX 4640.

Figure 35 is a monitor presentation of a stored video signal from a WX 4640 being scanned and read-out at standard TV rates. Figure 36 is the same video signal from the tube after the focus and scanning fields had been removed for 5 seconds, and the same total beam current had been converted into a flood-beam for the same period of time in the brighter area. Immediately thereafter, normal scanning was resumed. Figure 37 is the results of the same procedure after 10 seconds, and Figure 38 is the results after 2 minutes.

Figures 39 through 42 show a single horizontal line of video information held for the indicated periods of time by the same flooding technique. (For this series of tests, bars were written for clarity). The amplitude of the stored information remains nearly constant; however, as Figure 42 shows, the dark-current rises as it does when the target is scanned.

From these photographs it is obvious that a flood of electrons is capable of maintaining storage in a Permachon photoconductor.

#### WX 4821

Five WX 4821 scan-converters were constructed during the course of this contract; however, none of the tubes was sufficiently operable to enable the taking of quantitative data.



Figure 35. Original Stored Pattern



Figure 36. 5 Seconds

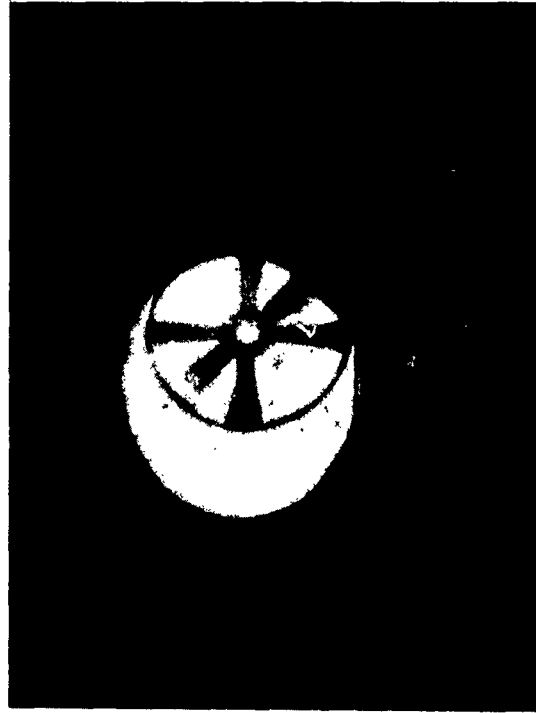


Figure 37. 10 Seconds

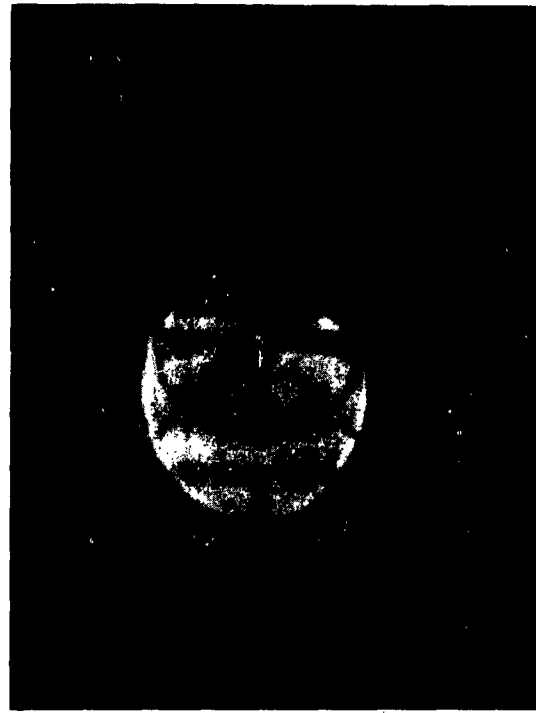


Figure 38. 2 Minutes

**Flood-Beam Holding (Monitor Presentation).**

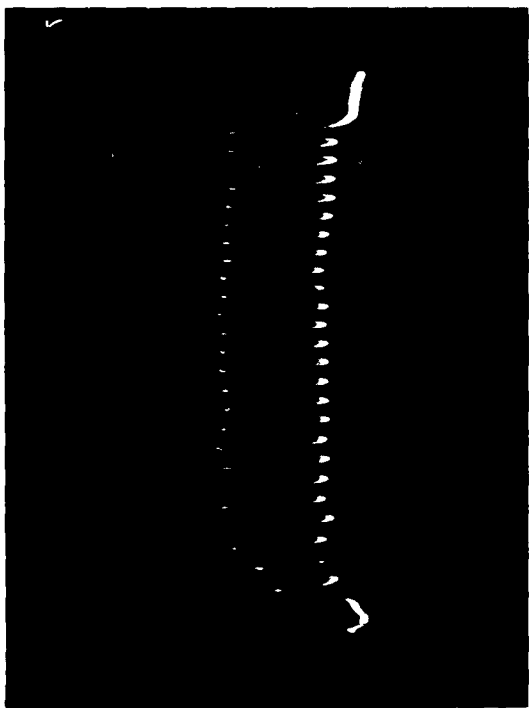


Figure 39. Original Stored Pattern

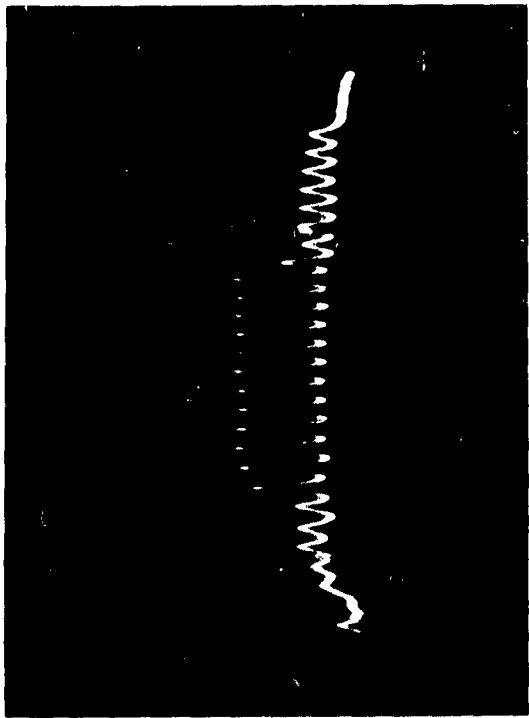


Figure 40. 5 Seconds

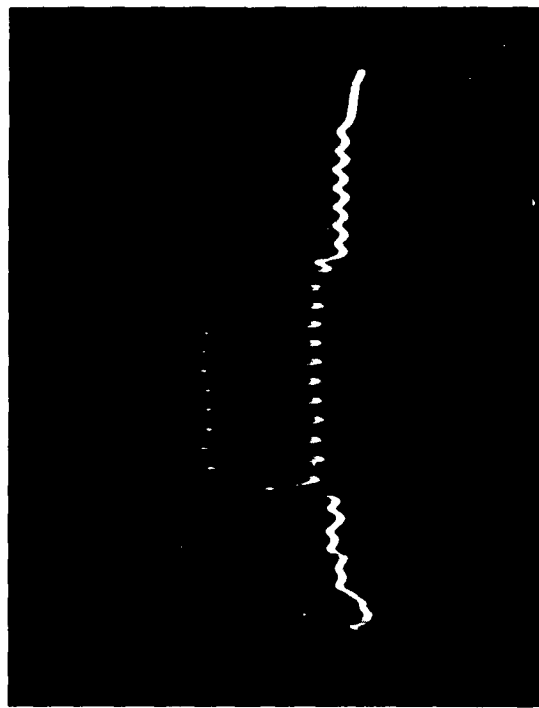


Figure 41. 10 Seconds

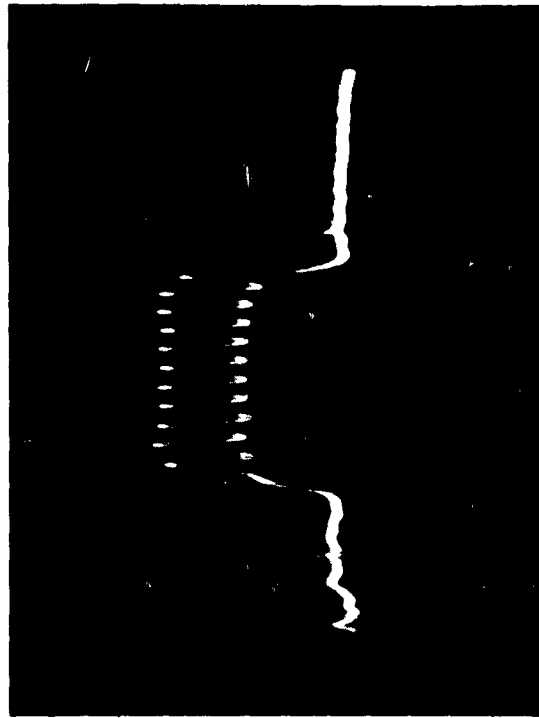


Figure 42. 2 Minutes

# Flood-Beam Holding (Video Signal)

## REVIEW OF TECHNICAL GUIDELINES AND COMMENTS ON DEGREE OF ATTAINMENT

### "Research and Development of a Scan-Conversion Storage Tube Based Upon The Permachon"

#### "1. Scope

1.1 Scope. This document covers the technical guidelines for a research and development program leading to the establishment of the feasibility and the demonstration of models of an electrical-input electrical-output storage tube based upon the Permachon camera tube of Westinghouse Electric Corporation.

#### 2. Applicable Documents

2.1 Technical Proposal for an Electronic Scan-Converter Tube, dated 1 March 1960, Westinghouse Electric Corporation, Electronic Tube Division, Elmira, New York.

#### 3. Requirements

3.1 General. The research and development to be performed under these guidelines shall be directed toward establishment of the feasibility of an electrical-input and electrical-output scan-conversion storage tube having the following characteristics:"

"3.1.1 Operating Functions. Three separate functions operating independently, and preferably simultaneously, shall be provided in the storage tube. The three functions are as follows:

- a. Writing
- b. Reading
- c. Erasure"

Any two of the functions listed can be performed independently, and any two can be performed simultaneously. To perform all three simultaneously would require the use of an external light flash for erasure, or the inclusion of a third electron gun within the tube.

"3.1.2 Electron Guns. Separate independent electron guns shall be provided for writing and reading. Consideration shall be given

to the feasibility of the inclusion within the tube of an additional electron gun for independent erasure, as described below. Consideration shall also be given to the feasibility of inclusion of an additional flood electron gun for regenerating the storage image pattern independently of reading."

These items have been considered, and with electrostatically focused and deflected guns, it is possible to include an additional electron gun for independent enhanced erasure.

A flood gun, as such, was not included in a tube; however, an electron flood generated by the WX 4640 reading gun did show that scanning is not essential to the retention of video information.

"3.1.2.1 Writing Electron Gun. The writing electron gun shall be capable of sufficiently high resolution to satisfy the overall resolution requirements of the storage tube, as described below. In initial experimental models of the tube the writing gun may be electromagnetically focused and deflected. In later models electrostatic focus and deflection shall be emphasized, in order to permit the inclusion of additional independent electron guns on the writing side of the storage target."

The WX 4640 will utilize electromagnetic guns, and later, in the WX 4821, electrostatic focus and deflection were emphasized.

"3.1.2.2 Reading Electron Gun. The reading electron gun may be electromagnetically focused and deflected, as in the normal Permachon. However, consideration shall be given to the feasibility of development of an electrostatically focused and deflected reading gun capable of sufficiently high resolution to satisfy the overall requirements of the storage tube, in case it should prove feasible to include a flood electron gun on the reading side of the target for regeneration of the image pattern."

Both types of guns were evaluated.

"3.1.2.3 Location of Writing and Reading Electron Guns. The writing and reading electron guns shall be situated on opposite sides of the storage assembly."

In all the dual-gun tubes, the guns were situated on opposite sides of an interjacent target.

"3.1.2.4 Erasing Electron Gun. The feasibility of erasure of a stored image pattern by means of an electron beam shall be studied. An overall erasure, either gradual or instantaneous, at the control of the operator, by means of a flood beam shall constitute one phase of this study. The ultimate goal, if erasing by means of an electron beam should prove feasible, is erasure of stored patterns from externally-selected elemental areas of the storage target without disturbance of the remainder of the stored pattern, simultaneously with continuous reading and writing. An electrostatically focused and deflected electron gun, situated on either side of the storage target as necessary, would be required."

Erasure performed with the writing gun (called enhanced erasure) and that performed with the reading gun (called unenhanced erasure) were both found to be feasible when used either independently or in combination.

Erasure by means of a flood beam was not studied.

Selective and/or partial erasure using both enhanced and unenhanced erasure were proven feasible, but not simultaneously with continuous reading and writing, although with the inclusion of an additional high-velocity electron gun this should be possible.

"3.1.2.5 Regenerating electron gun. Since it is apparent that regeneration of the stored image pattern by the unmodulated reading electron beam is essential to the long-duration storage in the normal Permachon target, and because it may be desirable in a scan-conversion storage tube to operate the tube with various types of reading scan pattern not necessarily suitable for this continuous regeneration process, it is desirable to investigate the feasibility of regeneration by means of a continuous, unmodulated, low-current-density electron flood upon the reading side of the target, operating simultaneously with the scanned reading beam. This function

would require an additional electron source to produce a uniform low-current-density electron flood covering the entire reading surface of the target. Operation of this electron source should not produce a noticeable effect on any of the other functions of the tube."

The feasibility of holding information with a flood of low-velocity electrons was shown, and it is not difficult to envision such a flood beam operating in combination with a scanning beam.

"3.1.3 Storage Target. The storage target shall be essentially the same as the target used in the Permachon camera tube. Modifications in the substrate may be made in order to achieve a more suitable means of writing and mechanical support, but the basic principles of operation of the Permachon target shall be retained in the storage tube and not altered in order to be more suitable for a particular method of writing. Improvements in the materials or processing which do not alter these principles may be incorporated in the storage tube."

The Permachon-type photoconductors were used almost exclusively throughout this contract.

"3.1.4 Method of Writing. Two methods of writing information into the target shall be investigated, direct electron beam writing by means of electron-bombardment-induced conductivity, and indirect writing by means of a composite target assembly, consisting of a high-resolution phosphor screen on one side of a high-resolution fiber-optics support plate, with the Permachon target and substrate on the opposite side. Other promising approaches to the writing function shall not, however be exhausted."

Both of these methods of writing were investigated and the fiber-optics approach was determined to be the better of the two for preserving the characteristics of the Permachon camera storage tube.

"3.1.5 Methods of Erasure. Methods shall be investigated for erasure of the stored information without recourse to external illumination. The preferred means of erasure is by action of an electron beam, as described in par. 3.1.2.4."



It was found that stored signals could be removed by removing the reading beam, flashing the target with a burst of electrons from the writing gun, or both.

"3.1.6 Target Recovery After Erasure. A study shall be made of the recovery process occurring in the Permachon target immediately after erasure, with the intent to minimize or eliminate the resulting disturbance, both in duration and magnitude."

This process, termed charge-down, was investigated, and the results are given in this report in the section on tube characteristics.

"3.1.7 Writing Speed. With television-type raster scans applied to both writing and reading electron guns, a pattern shall be written into storage on the storage assembly. A high-resolution television waveform monitor oscilloscope, having sufficient video bandwidth and linearity to avoid degrading the signal waveform or affecting the amplitude display, shall display the signal produced by the reading function of the storage tube. Using counted individual writing frames, it is an objective of this program that the tube shall be capable of writing into storage in one television frame of 1/30 second a charge pattern which will produce in the output current electrical signals having at least 75% of the amplitude which the signals from the same portion of the scan would produce when the largest signal in the pattern reached its saturation amplitude by repeated writing."

Writing speed data have been given in previous reports, and in no Permachon scan-conversion tube has it been possible to write to 75% of saturation in 1/30 of a second. The best writing speeds obtained using a P-20 phosphor input were approximately 75% of saturation in 1/3 of a second, and storage was not optimum under such input conditions.

"3.1.8 Output Resolution. The electrical output signal produced by the storage tube under the conditions described in par. 3.1.7 should indicate a resolution of at least 625 television lines at 75% contrast ratio (modulation 75% of peak amplitude)."

This requirement was partially fulfilled, and the

best resolution seen has been 600 TV lines per inch at 20% response factor. It is expected that the WX 4821 will provide substantially better resolution.

"3.1.9 Retention of Stored Information. Stored information written to saturation, as in par. 3.1.7, should remain usable, with no more than 20% deterioration in amplitude or resolution, as seen in the reading output signal on the waveform monitor, for a period of at least 15 minutes after the last writing raster scan."

This factor has varied from tube to tube, and a 50% deterioration in amplitude in 15 minutes is typical. Limiting resolution is not seriously affected by storage duration.

"3.1.10 Output Dynamic Range. The average maximum amplitude of the signal which may be read out of storage should be at least 100 times the average maximum amplitude of the output noise signal, including shading, baseline curvature or tilt, and mesh screen disturbances."

This parameter varies with the amplitude of the stored information and the duration of storage. For short durations of storage ( $< 1$  minute) the peak-to-peak signal to peak-to-peak noise ranges typical from 17-to-1, to 29-to-1.

"3.1.11 Output Modulation Range. It shall be possible to store signals which will produce a full range of output current amplitudes between the maximum amplitude of signal saturation and the noise level."

It is possible to store such a range of signals, although gamma correction must be provided to the input signal voltage to compensate for the non-linear transfer function of the writing-gun triode.

"3.1.12 Integration. By writing with a low beam current it should be possible to reproduce output current signals which increase in amplitude with number of writing scans up to at least twenty writing scans."

This capability is inherent in the Permachon photoconductors.

"3.1.13 Variation of Output Current. The variation of the maximum output current amplitude measured over the storage surface shall not exceed five percent of the average maximum amplitude."

After a signal is initially stored this variation can be held within 5%; however, with the rise in dark current and the introduction of base line curvature this variation increases.

"3.1.14 Physical Size. The physical size of the storage tube shall be kept to a minimum consistent with the required operations."

Two sizes of tubes have been built: the WX 4640 is 16-1/2 inches long and has a maximum diameter of 1.45 inches, and the WX 4821 is 31 inches long and has a maximum diameter of 3 inches.

#### 4. Quality Assurance Provision

4.1 Testing and Inspection. The tube models developed under this specification will be inspected by USAEL personnel to determine compliance with the requirements of this specification."

## OVERALL CONCLUSIONS

The work performed on this and the preceding scan-converter contract has made known both the advantages and limitations of a scan-converter that utilizes a Permachon photoconductor to store information.

In general, the smaller tube, the WX 4640, has been developed to a point where it can go into a pilot-production program. The larger all-electrostatic tube, on the other hand, has not been fully developed (only six tube starts have been made), and additional work will be required before quantitative evaluation of this tube configuration can be made.

Some of the advantages offered by the Permachon scan-converter are:

1. Multicopy readout.
2. Integration of inputs while reading out.
3. Partial erasure.
4. Selective erasure.
5. Small size.
6. Simplicity of operation.
7. Internal input-output signal separation.

Some of the basic limitations of the tube are:

1. Sensitivity to temperature.
2. Rise of dark-current.
3. Speed of writing.

The developments of this program can now be used only for tubes with Permachon characteristics, but also for tubes of similar mechanical configuration and different targets and conversion characteristics.

## RECOMMENDATIONS

It is recommended that the development of the scan-conversion tube be continued, especially with regard to the WX 4821.

Items that should be studied within a scan-converter tube embodiment or that of a single-gun camera storage tube are itemized below:

1. The fiber-optics which are a basic part of this tube should be further investigated. For example, a program may be set up in conjunction with fiber-optics manufacturers for making special plates which will be evaluated for: ease of coating with a transparent conductor, maximum aperture-response, and freedom from blemishes in the output signal. The best of each of these characteristics has been seen separately, but not in the same plate.
2. Different types of phosphor should be evaluated for their compatibility with the Permachon photoconductor under various operating conditions in an FOPT scan-converter. The only type used during this contract was a cataphoretically deposited P-20.
3. The electron optics of both tubes should be more thoroughly evaluated and optimized to enhance resolution. In the WX 4640, for example, some of the new higher-electron-velocity and separate-mesh vidicon guns should be studied.
4. The processing schedules of both tubes should be analyzed carefully to insure that the best methods are being used. This should be done in conjunction with both dynamic and static life-testing.
5. Basic research on the Permachon effect should be performed in an effort to understand better the principles of its operation. In this way, it will be possible to introduce modifications which should be able to improve the operating characteristics; in particular to reduce dark-current and temperature-dependence.

6. A methods-and-techniques study should be made to determine a way whereby the complex FOPT target can be constructed without introducing blemishes that appear in the output video signal. In this area, a suitable substitute for stannic-oxide coating should be found, which is compatible with the Permachon photoconductor.

## PERSONNEL

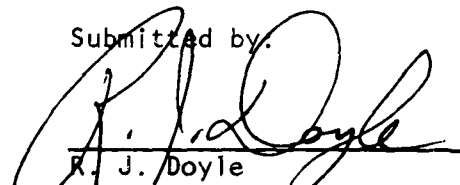
During the period of this contract, approximately 6,367 engineering man-hours were devoted to the design and development of scan-conversion storage tubes based upon the Permachon camera storage tube. Approximately 1,613 hours of this time were applied during the last quarterly period. A list of the persons who contributed to this effort is supplied below, and biographies of the key personnel involved are included on the following pages.

<u>Engineers</u>	<u>Last Quarter</u>	<u>Entire Contract</u>
L. G. Bonney	3	17
R. J. Doyle	240	1,586
J. McIntyre	14	62
H. Moss	0	6
J. Nicholson	0	8
E. E. Selby	15	106
R. A. Shaffer	<u>25</u>	<u>136</u>
	297	1,921
<u>Technicians</u>		
G. G. Gresock	447	1,689
M. Morseman	424	1,334
Others	<u>445</u>	<u>1,423</u>
	<u>1,613 hrs</u>	<u>6,367 hrs</u>
Grand Total Both Contracts	22,163 man hours	

Approved by:

  
R. A. Shaffer  
Supervisory Engineer  
Image Tube Department

Submitted by:

  
R. J. Doyle  
Project Engineer  
Image Tube Department

Leo G. Bonney, Jr.

Education

Lehigh University, B.S. in Chemical Engineering, 1958  
Cornell University, 1 semester toward Ph.D in Inorganic Chem., 1959

Professional Experience

1958 - 1959 - Cornell University, Ithaca, New York. Teaching Assistant  
in Freshman Chemistry.

1959 - date - Electronic Tube Division of Westinghouse Electric  
Corporation, Elmira, New York. Chemist, Camera Tube  
Engineering Section.

Accomplishments

Co-submission 7 disclosures in 5 years of employment; 4 on storage  
targets and one Most Meritorious Award for a disclosure concerning  
the storage orthicon; 2 on scan-converter targets.

Recognition

Tau Beta Pi, Pi Mu Epsilon, teaching assistantship at Cornell  
University, Bradford County Scholarship, American Viscose Corp.  
Scholarship.

Affiliations

American Chemical Society



Robert J. Doyle

Education

Northeastern University, B.S. in Electrical Engineering, 1959

Professional Experience

1955 - 1959 - Raytheon Company, Microwave and Power Tube Division;  
Development of microwave and storage tubes.

1961 - date - Westinghouse Electronic Tube Division; Development  
of image tubes.

Military Service

1959 - 1960 - U. S. Army Signal Corps, Fort Monmouth, New Jersey.  
Microwave Tube Branch of USAELRDL. Research into  
microwave devices.

Affiliations

Member of the IEEE.

James L. McIntyre

Education

Milwaukee School of Engineering, A.A.S. in Electronics, 1951.

Professional Experience

- 1951 - 1952 - Bell Aircraft Corporation, Niagara Falls. Worked as trouble shooter and technical writer, Guided Missiles Section.
- 1952 - 1957 - Westinghouse Electric Corporation, Elmira, New York. Process Engineer, Cathode Ray Tube Department.
- 1957 - 1958 - New Products Division, Corning Glass Works, Corning, New York. Process Engineer, Assembly and Testing of Ultrasonic Delay Lines.
- 1958 - 1962 - Electronic Tube Division, Westinghouse Electric Corporation, Elmira, New York. Manufacturing Engineer, Image Orthicons.
- 1963 - date - Electronic Tube Division, Westinghouse Electric Corporation, Elmira, New York. Engrg. Supervisor, Image Tube Technology Lab; responsible for process design and fabrication of all experimental image and camera tube types.

Military Service

1945 - 1946 - U. S. Army, Supply Sergeant in Prisoner of War Camps.

Accomplishments

One patent on oxide coated cathodes.  
One patent on image orthicon guns.  
One patent filed on Image orthicon gun.  
Meritorious Disclosure Award, 1961.  
Development of rugged image orthicon, WL 7198.  
Development of S-10 and S-20 cathodes.

Dr. Hilary Moss

Education

- |      |   |
|------|---|
| BSEE | University College, Southampton,<br>England |
| PhD  | Electron Physics, University of London      |

Professional Experience

- |                    |  |
|--------------------|--|
| 7 years            | Department Manager of Cathode Ray Tubes for A. C. Cossor,<br>London, England.  |
| 5 years            | Chief Engineer and Director of Research for Electronic<br>Tubes, High Wycombe, England   |
| 1 year             | Chief Engineer for Electronic Tube Corporation,<br>Philadelphia, Pennsylvania  |
| 4 years            | Department Manager and Consulting Scientist for<br>Burroughs Corporation, Paoli, Pennsylvania  |
| 1957 to<br>Present | Advanced Development work on cathode ray tubes and<br>electron gun optics, as Advisory Engineer at Westinghouse<br>Electric Corporation, Elmira, New York. |

Dr. Moss has published a large number of papers on electron gun optics, and is recognized as one of the foremost electron gun optic engineers in the world.

Dr. Moss has recently been awarded the High Doctorate (D.Sc.) University of Southampton, England.

James F. Nicholson

Education

Iowa State College  
Bradley University, B.S. in Physics, 1951.

Professional Experience

1951 - 1956 - Electronic Tube Division of Radio Corporation of America, Lancaster, Pennsylvania. Work on 10 inch tri-color kinescope, high resolution monitors, high voltage projection tubes, Williams storage tube, Image orthicon and vidicon tube types. Designed first color vidicon camera, designed 20 MC video amplifiers, and was involved in application problems on all associated tubes. Chief Engineer at TV experimental station Kg2XD1-1954-1956.

1956 - date - Fellow engineer. Electronic Tube Division of Westinghouse Electric Corporation, Elmira, N. Y. Project engineer for photosensitive pickup and storage tubes. Has been responsible for devices from concept through production, including associated processes and operational equipment. Presently engaged in high resolution device design and application engineering associated with various pickup tubes made by Westinghouse.

Military Service

1940 - 1945 - U. S. Coast Guard - Aviation and shipboard radio operator and aviation radio technician.

Accomplishments

5 patents and several disclosures  
Commercial pilot license, instrument rating  
Radio telephone license first class  
Radio amateur license advanced class

Elmer E. Selby

Education

The College of Wooster, B.A. in Mathematics, 1952  
MIT, B.S. in Chemical Engineering, 1953

Westinghouse Graduate Student Program, including 1954 Design School  
(12 hours of graduate credit in mathematics, mechanical engineering,  
and electrical engineering from the U. of Pittsburgh)

Professional Experience

1953 - date - Westinghouse Electric Corporation. Since 1954, Electronic  
Tube Division, Elmira, N. Y. Assignments in:

Technical Services Department - Engineering development  
of new materials and processes and factory trouble-shooting,  
primarily in the fields of phosphor screen applications,  
including electrophoretic deposition of high resolution  
screens; materials for photocathodes; internal conductive  
coatings; and component cleaning. Experience in the  
emission spectroscopy of electronic tube materials.

Image Tube Manufacturing Department - Experience in the  
production of electroformed, fine-mesh screens, component  
cleaning, and the operation and monitoring of clean  
environments for tube processing.

Image Tube Engineering Department - Senior Engineer,  
responsible for development and model shop production of  
phosphor screens, with emphasis on high resolution types,  
and the design and operation of clean environments.

Accomplishments

One patent issued on the deposition of phosphor screens.  
Article on airborne dust monitoring published in ASTM.  
Special Technical Publication 342.

Affiliations

Senior member of the ACS. Former member-at-large of Executive Council  
of Corning Section.

Westinghouse representative to ASTM Committee F-1, Subcommittee VII  
on Luminescent Materials and Subcommittee X on Control of Contaminants;  
Chairman of Subcommittee X, Section B on Surface Examination.

Member of the American Assoc. for Contamination Control.

Robert A. Shaffer

Education

Colgate University, B. A., 1950  
Air Force Electronic Schools

Professional Experience

Since 1954 - Electronic Tube Division of Westinghouse Electric Corporation, Elmira, N. Y. Engineer, Cathode Ray Tube and Image Tube Development Sections specializing in development of thin film techniques, secondary emission surfaces, and electroformation techniques. Project engineer and Supervisory Engineer of Image Orthicons and Allied Types.

Military Service

1950 - 1954 - U. S. Air Force. Third & Fourth Echelon Maintenance of Radar, Radio, Navigational Test Equipment.

Accomplishments

Patent on Technique for producing a fine mesh pattern on a substrate. Co-submission of 4 disclosures on storage targets.

Patent on an electron discharge device (electron gun modification)

Eight disclosures accepted on thin film and electroforming techniques. Three disclosures are in process.

Developed techniques for making thin films, for electroformation of fine mesh structures, for secondary emission surfaces, and for specialized vacuum evaporations.

Most meritorious disclosure award for thin film orthicon target.

Three engineering reports on electroformation of fine mesh structures.

Development of thin film target image orthicon and intensifier image orthicon.

Affiliations

Member of Alpha Chi Sigma

## APPENDIX

### Introduction

In addition to the research and development performed under this and the preceding contract at the Electronic Tube Division, studies have also been conducted by workers at other Westinghouse Divisions to evaluate the characteristics of the Permachon camera storage tube. The results of their findings are reported here, in order that this report, in combination with the fourteen prior reports, will provide a comprehensive presentation of the Permachon capabilities and limitations, as they were found in both the camera storage tube and the scan-converter.

### Sequenced Operation from a CRT

A series of tests have been conducted using a 7ABP-31 cathode-ray tube (CRT) optically coupled to a one-inch Permachon camera storage tube. Figure 43 is an oscilloscope presentation from a photomultiplier, which shows a typical set of illumination sequences that were coupled to the Permachon. The sequence consists of an erasure cycle of maximum brightness, during which time the Permachon is biased off, a charge-down cycle of 2 TV frames duration, and a writing cycle of 1 TV frame. Figure 44 is a photograph of the output signal from the Permachon after the completion of such a cycle.

Although this is not the best picture that can be read from a Permachon, it does show that it is possible to write in one TV frame, store, and read out a recognizable pattern. Further work will probably improve this performance.

### General Permachon Evaluation

A Permachon tube was operated in a vidicon TV camera with standard line and frame rates. Illuminations in the range from 0.9 to 0.07 ft-c. were produced on a small area of the Permachon target. The resulting video signals were displayed on a very-slow-sweep oscilloscope after amplification and gating. Photographs of the oscillograms were used for determining signal

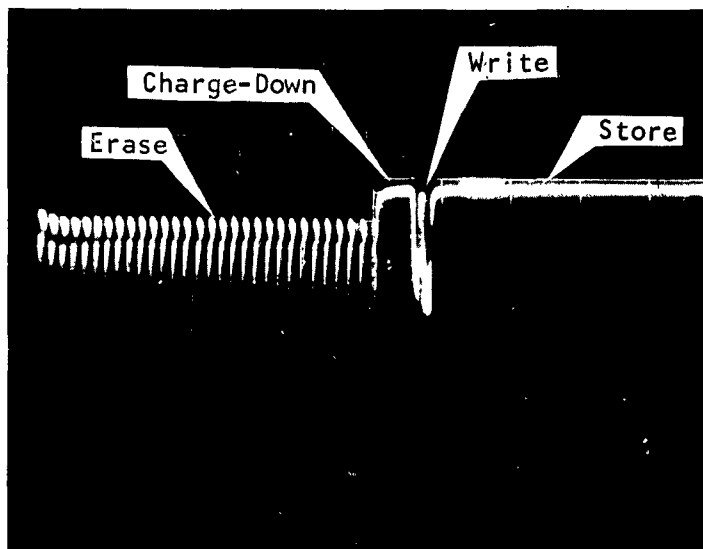


Figure 43. Illumination Sequence 100 MS/cm

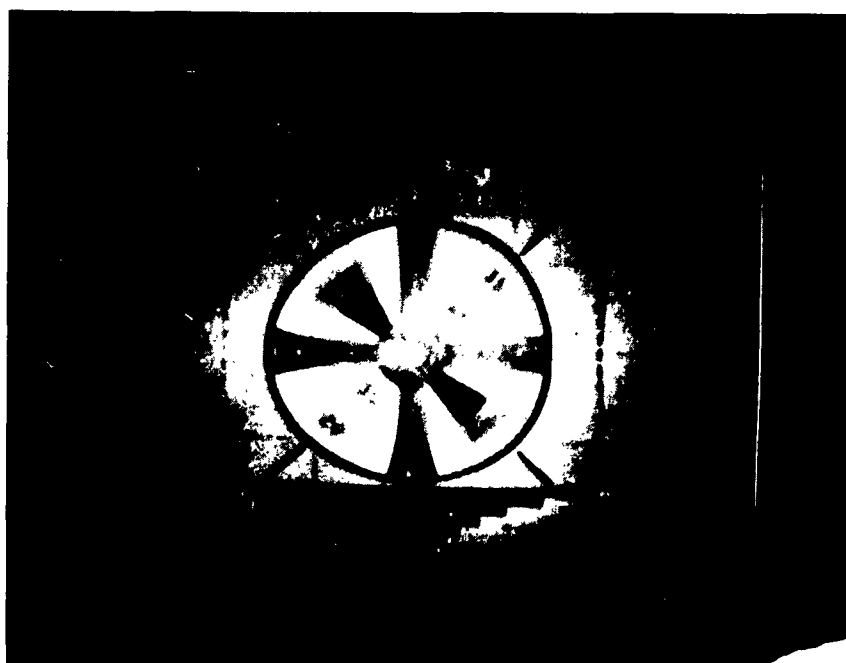


Figure 44. Stored Signal



currents. For comparison a vidicon type 6198 was also measured in the same equipment.

The video output from a vidicon reaches full value within 2 or 3 fields, i.e., in about 1/20 sec. This output is not proportional to the target illumination but follows a 0.6 to 0.8 power law. The video output from the Permachon rises with about the same speed to an initial value which, on the average, is of the same magnitude as with the vidicon. The initial output of the Permachon is, however, proportional to the target illumination. After the initial value or step, a slow build-up follows, which in the beginning is linear but gradually attains a decreasing slope until a saturation value is reached. The final saturation value is independent of the strength of target illumination. The exposure time required, however, is greatly dependent on the illumination. First, the initial slope is proportional to the illumination value, and second, the deviation from linear build-up increases with time; the assumption, therefore, that a very low scene brightness may be compensated for by prolonged exposure may not always be applicable. In applications, however, where a stationary scene of very long duration can be provided, a good picture may be obtained at considerably less brightness than required for the vidicon.

The transfer efficiency is dependent on the beam current, the build-up being lower for beam currents smaller than the optimum value. At beam currents below optimum the build-up does not approach saturation asymptotically but overshoots.

Video Build-Up. Figure 45 shows the video build-up measured with f/8 optics, corresponding to a target illumination about .28 ftc. The output is seen to rise steeply during about four fields (1/15 sec) and then assume a slow linear build-up. The first part corresponds to the output of a regular vidicon and is of about the same magnitude. The latter part represents the integrating property of the Permachon. Similar curves for other f-stops (other target illuminations) have the same general shape and are, therefore, not included in the report.

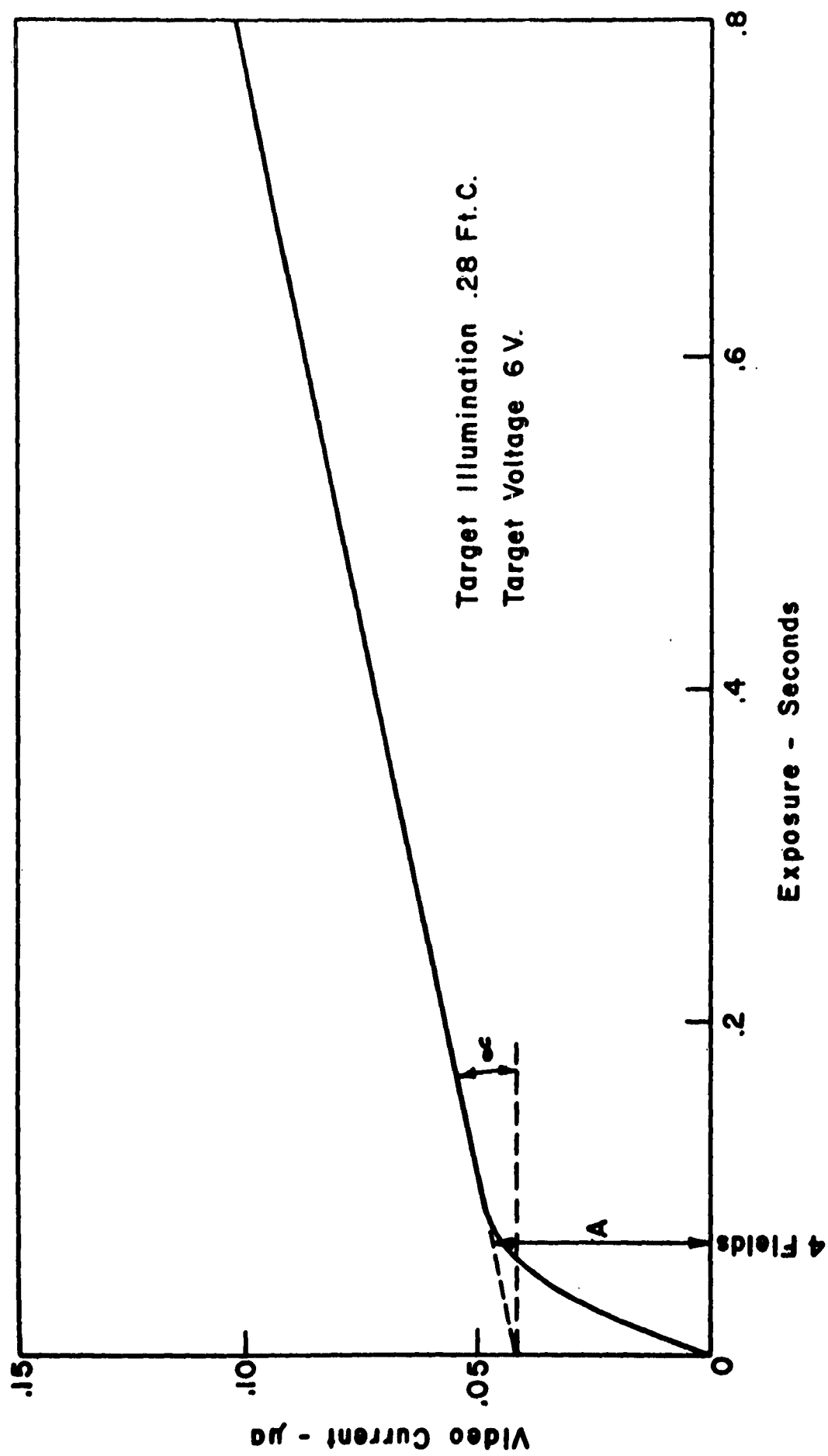


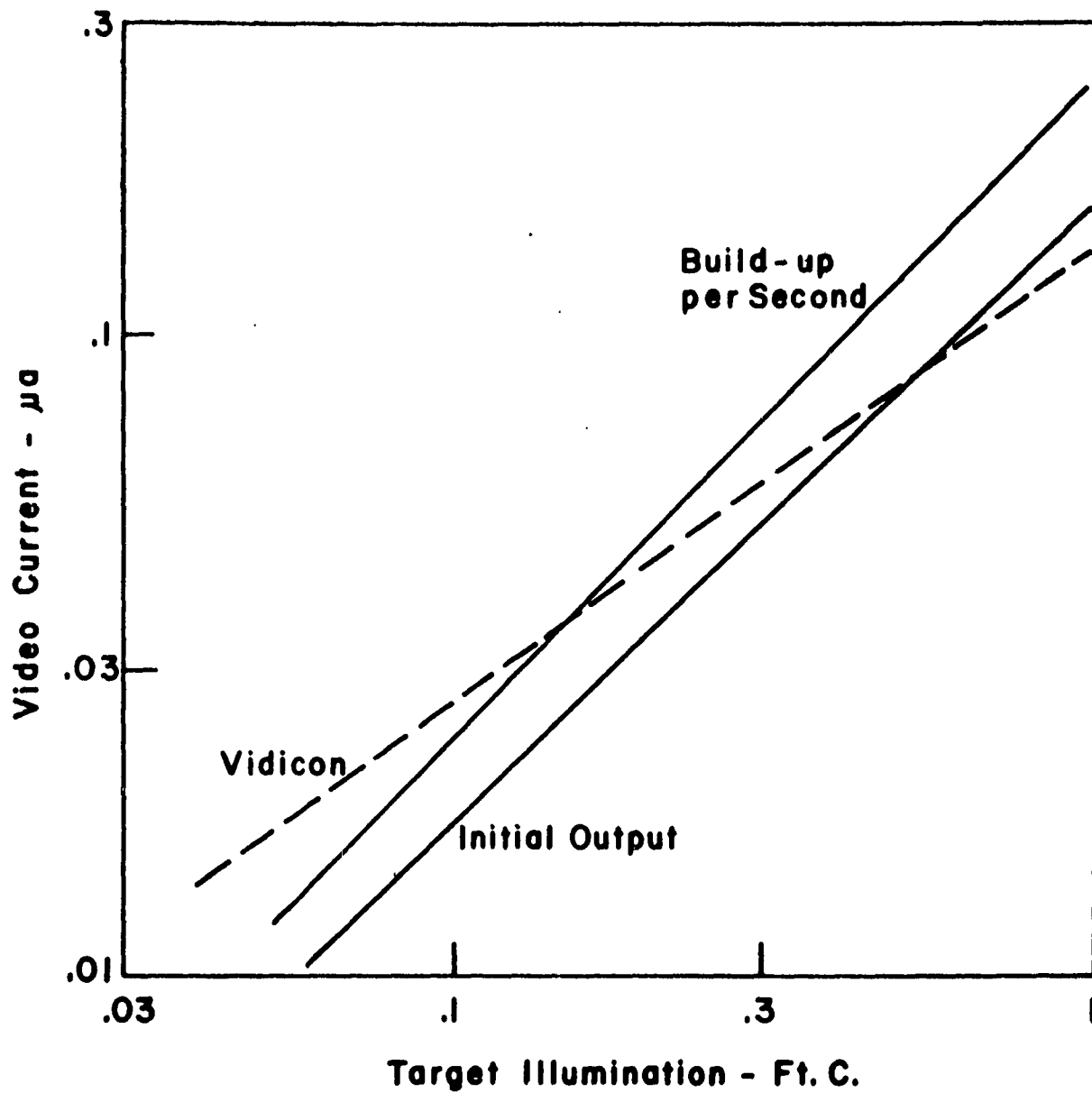
Figure 45. Video Signal Build-up

Relationship to Illumination. The magnitude of the initial step (A in Figure 45) naturally depends on the value of illumination. The slope ( $\alpha$  in Figure 45) or rate of build-up is not a constant but is also a function of the target illumination. When these magnitudes are read off the several build-up curves and plotted versus target illuminations, Figure 46 is obtained. The points representing initial output (step) as well as build-up (slope) are seen to fall on straight lines on the logarithmic scale. Within the accuracy of our measurements both lines have a  $45^\circ$  slope. Consequently both initial output and rate of build-up are proportional to target illumination. This relationship differs from that of the vidicon, the output of which follows a .6 to .8 power law versus target illumination and has no build-up. The dotted line in Figure 46 shows the output of a vidicon measured in this equipment (40 volts on the target.)

As seen in Figure 46, the amount of build-up per second is a little more than the initial output. An exposure of about 10 seconds, therefore, increases the output an order of magnitude. The initial output of the Permachon falls off more rapidly towards low illumination than does the output of the vidicon. The vidicon, therefore, may give a better picture of low-brightness scenes of short duration. With scenes allowing prolonged exposure, however, the Permachon will gain advantage.

Departure from Linear Build-Up. The build-up in Figure 45 was seen to be linear with time. This holds true for the first few seconds. The signal build-up has an upper limit which is the same for all target illuminations. With strong illumination and consequently steep build-up, this saturation naturally restricts the duration of linearity.

Figure 47 shows the signal build-up for various brightnesses and durations long enough to give saturation. The rate of build-up was previously found to be proportional to the illumination. The several curves are, therefore, plotted with different time scales so that the abscissa is compressed proportionally to target illumination. The build-up curves consequently start off as parallel lines. The 0.9 ftc. build-up curve is seen to rise linearly with a very short transition into the saturation value. The lower-illumination curves depart from linearity at lower and lower signal



**Figure 46. Initial Signal and Rate of Build-up Vs. Target Illumination**

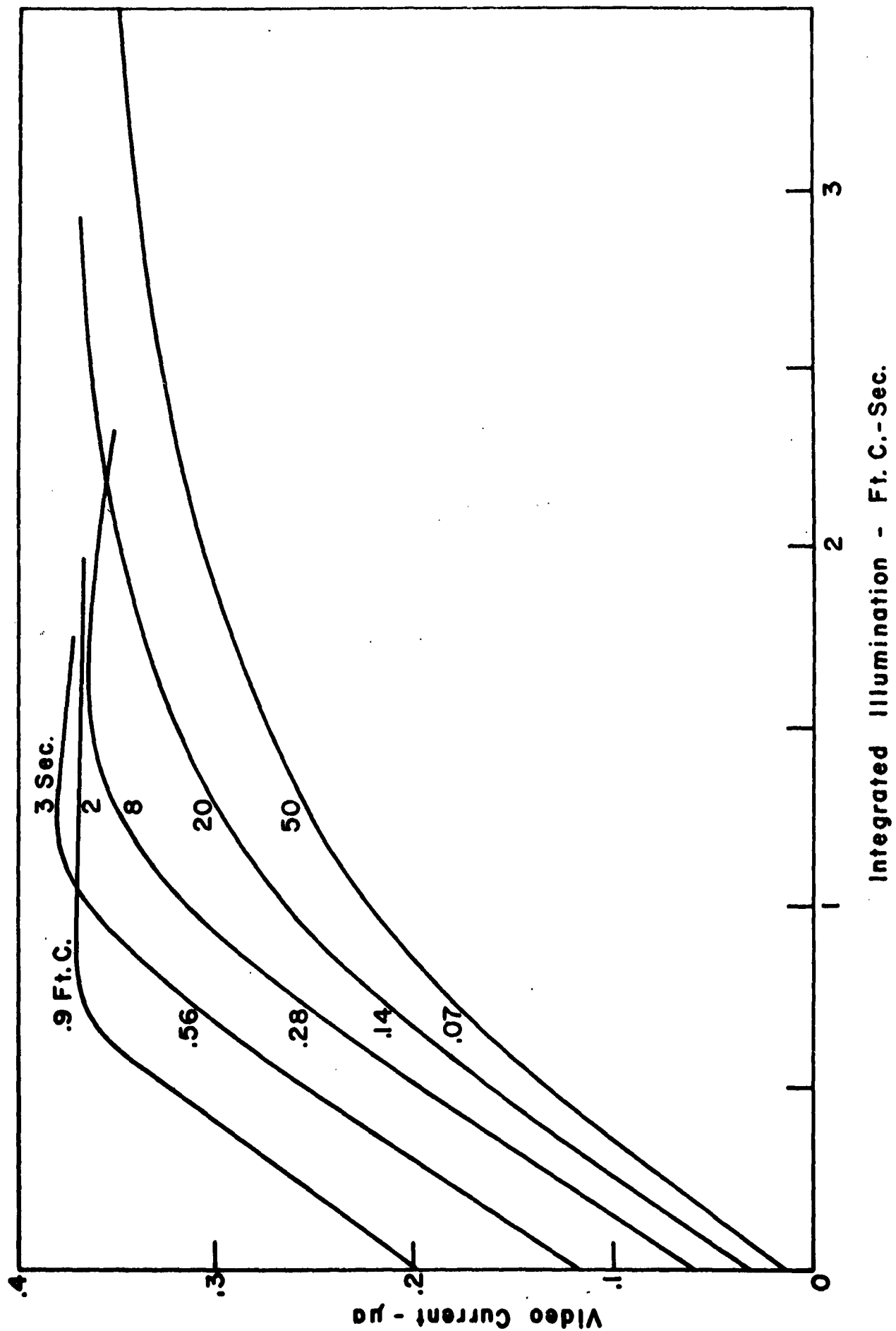


Figure 47. Comparison of Long-Duration Build-up at Different Illuminations

values. This does not, however, mean that the curvature becomes noticeable after a shorter duration of exposure at low light-levels. Since the curves are plotted versus the product of illumination and exposure, the time scale is more and more compressed towards lower illumination. For clarity the end points of the several curves of Figure 47 are marked. No measurable departure from linearity occurs during the first few seconds, except when the illumination is so strong that saturation is approached in this time. The lowest curve, however, has not reached saturation even after 50 seconds (end of graph), and a considerable departure from linearity is evident. A leakage of the charge on the target or a decay simultaneous with the build-up would give this type of curve.

Analysis of Build-Up Curve. An analysis of the build-up curves has been attempted. It appears the best fit to the measured curves is obtained by an expression of the form  $K_1 + K_2 (1 - e^{-t/K_3})$  i.e., similar to the charging of a leaky condenser. This match is shown in Figure 48 for the two lower curves of Figure 47. Both curves probably match within the accuracy of the measurements. Figure 49 shows the curve for 0.28 ftc. of a later measurement after some changes in equipment. Great care has been taken for accuracy. The curve according to the exponential equation is seen to match accurately the measured points.

For application purposes, it appears satisfactory to assume linearity for the first few seconds. When the target illumination is low and the exposure long, the exponential expression may be used.

Effect of Beam Current. The signal build-up versus illumination and time, as shown in Figures 45-47, is true only for one particular beam current. A change of beam current would give different values. Figure 50 illustrates the effect of such changes. The grid voltage rather than beam current is used as a parameter, since it is easier measured. Operation with beam current below optimum does not greatly affect the rate of build-up but results in a low saturation level, which consequently is reached after a shorter excitation. It further appears the beam current is insufficient

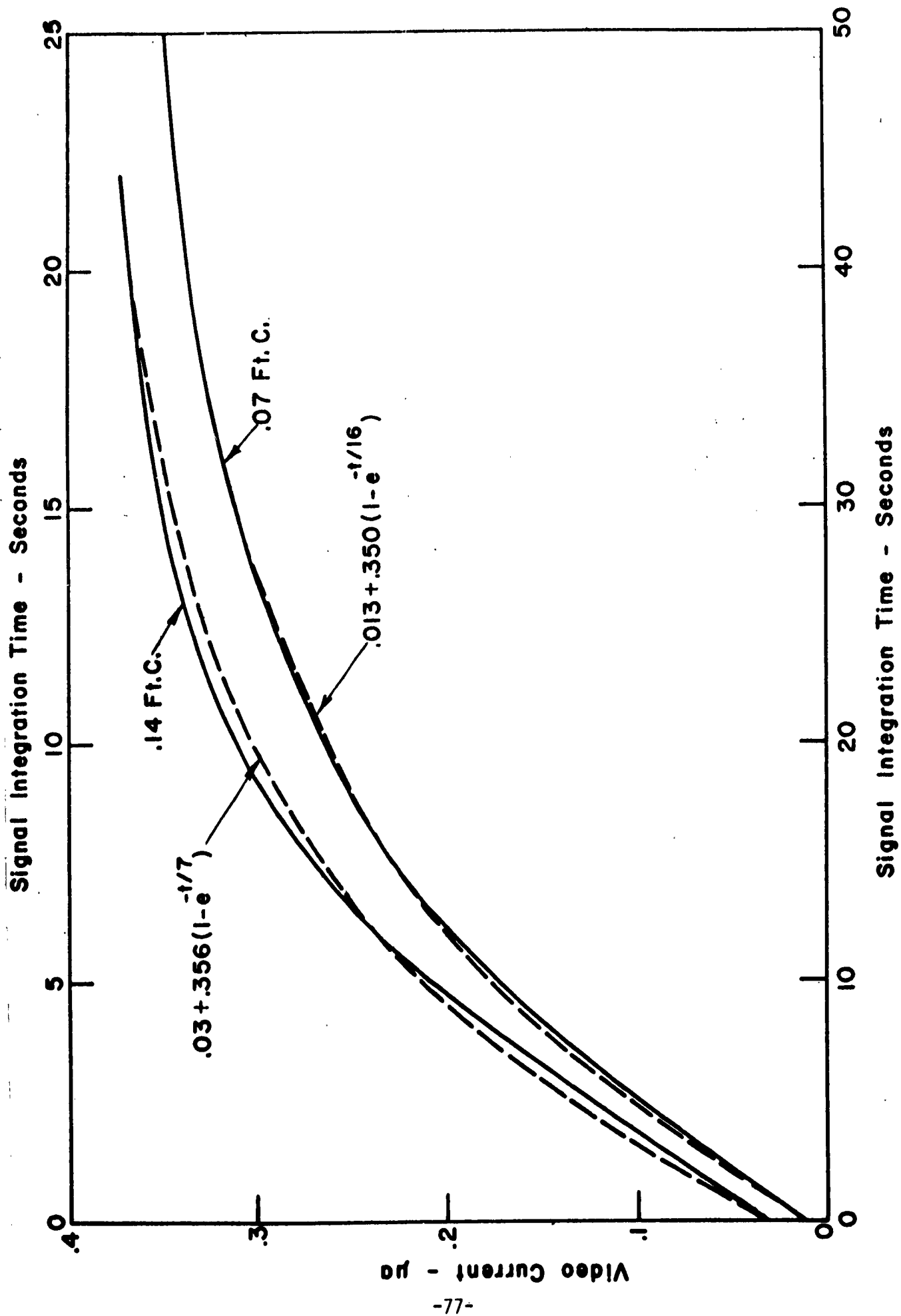


Figure 48. Analysis of Signal Build-up

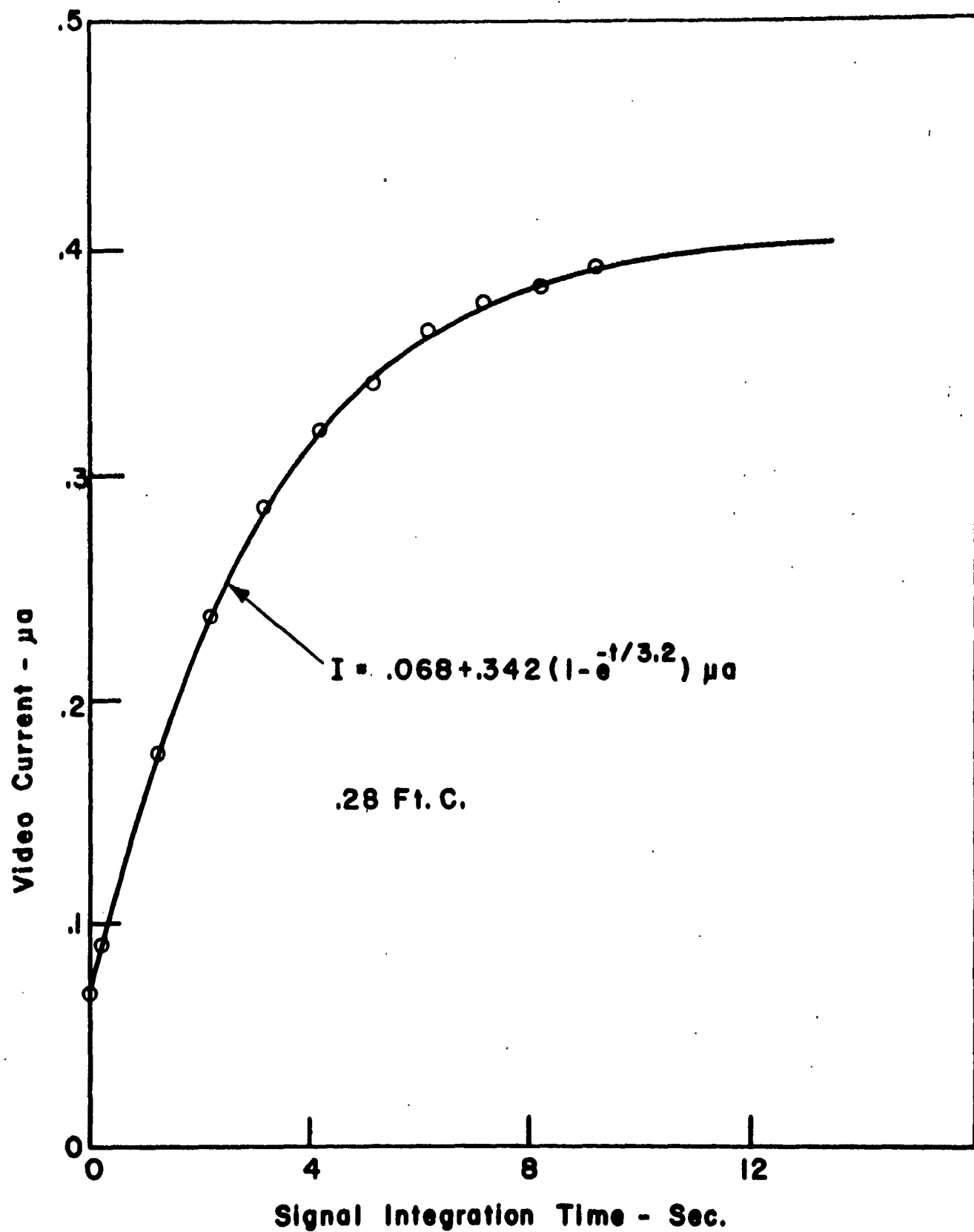


Figure 49. Analysis of Signal Build-up



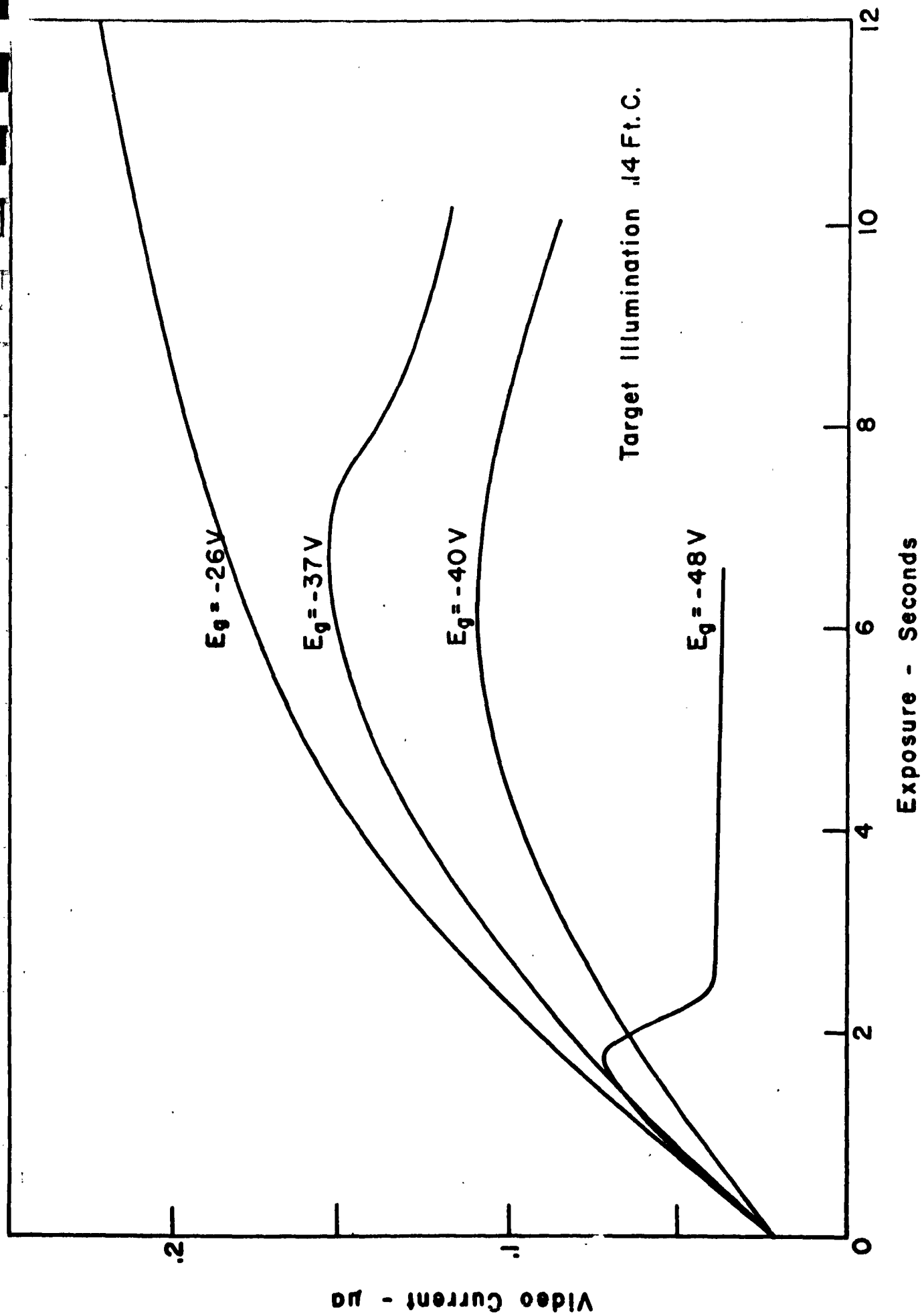


Figure 50. The Effect of Beam Current on Signal Build-up

for maintaining even this lower value, since the output again decreases after reaching the saturation value. Exceeding the optimum beam current does not appear to be critical.

Decay After Capping the Lens. When the lens is subsequently capped, the 48V curve does not show any change in its slow rate of decay. The 40V and 37V curves get a step up to about the same value as their respective previous peaks, when the lens is capped. A rather slow decay follows this step. The 26V curve falls off when the lens is capped, rapidly in the beginning and then flattens out. The decay follows a curve like the voltage across a condenser which is discharged to a lower voltage via a resistor. In spite of the quick drop, the trailing part remains higher than the decay curves at the three other grid values.

#### The Permachon at Slow-Scan Rates

Measurements of initial signal output, build-up (integration), and storage versus scene-illumination have previously been made. In those measurements, which are described under General Permachon Evaluation, the frame rate was held constant at the usual 30 frames/sec. The following measurements were made at various frame rates from 1 frame/sec up to 60 frames/sec. Most of the measurements were made with one illumination only, viz. 0.28 ftc. on the target.

Measurements of 20 frames/sec and higher were made with the same camera (GPL PD-150) with some modifications. For the lower frame-rates special equipment was made.

Test Results. Figure 51 shows two representative build-up curves, viz. at 2 frames/sec and 10 frames/sec (for measurements at 30 frames/sec, see General Permachon Evaluation). It is seen that the low rate gives a lesser output than the higher rate, as anticipated. Furthermore, at low frame rates the illumination is not integrated, as seen by the absence of signal build-up (no slope on video current vs time of exposure). A small build-up was found at about 5 frames/sec. At higher frame rates the build-up increases.

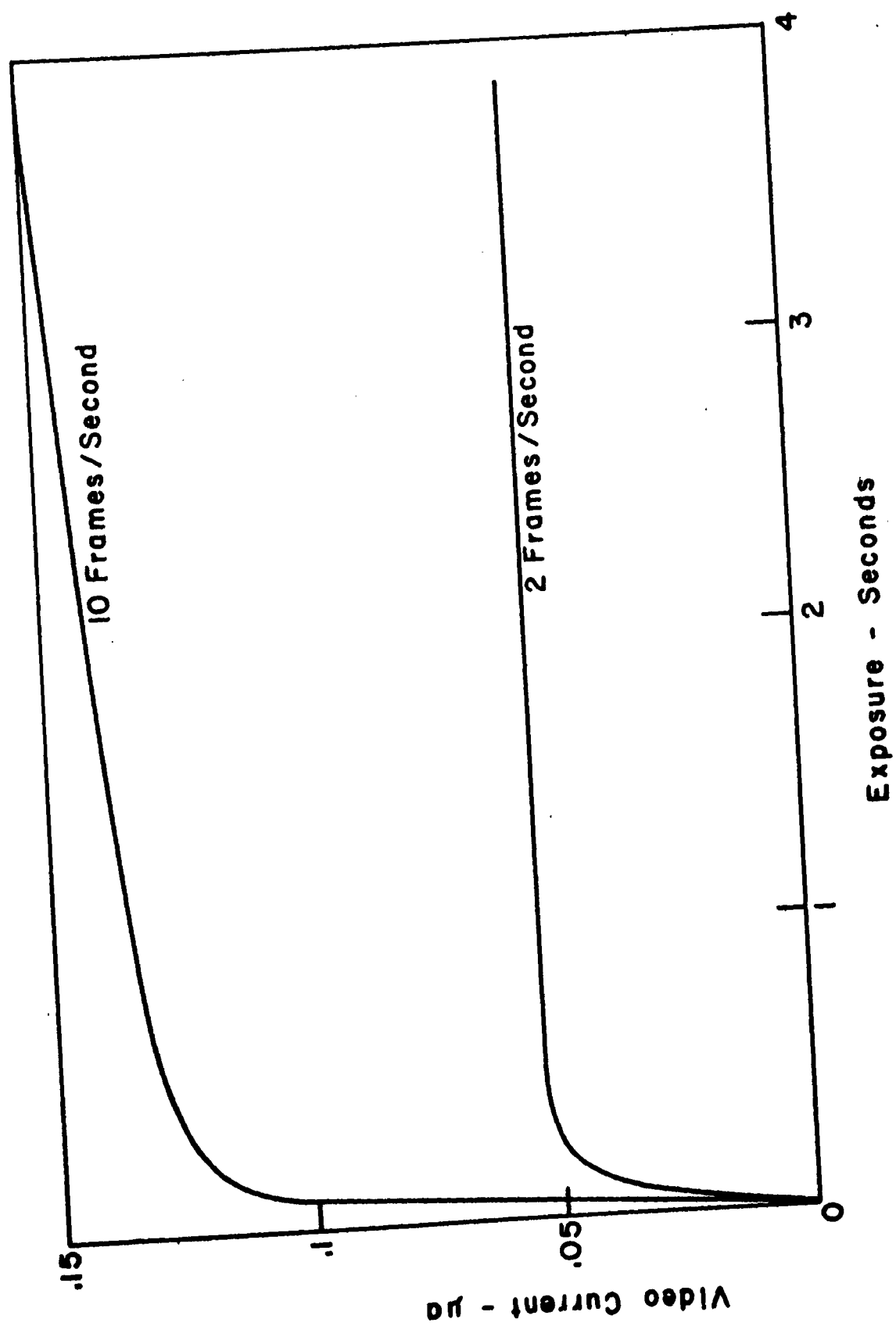


Figure 5l. Signal Build-up with 0.28 Ft.C. Target Illumination

The steep part of the video output curves (or step, is, in general, not attained during the first field (the first time the beam strikes the target element) but consists of a rapid build-up during a few fields. Following this region of rapid build-up, there comes a region of very slow build-up, which continues until the saturation level is reached. With the slow-scan the first region consists of one or two fields only, whereas with fast scans it may cover five or more fields.

The value attained during the first region (the value at the knee) is plotted against frame rate in Figure 52. Below 4 frames/sec the output is independent of the frame rate. The individual measurements in this range show no build-up. Above about 4 frames/sec the initial output increases with frame rate. The individual measurements in this range also show the build-up in the second region (integration) peculiar to the Permachon.

At about 20 frames/sec. the curve again falls off. This behavior is difficult to explain. The measurements were, therefore, repeated at a lower illumination. The same results were obtained, as seen in Figure 53. The frame rate at which fall-off occurs is now shifted slightly upwards. This change is, however, not significant considering the tube's extreme sensitivity to temperature. A good explanation for the fall-off has not yet been found.

Although the initial signal value (the knee of curves similar to Figure 51) falls off at the high frame-rates, build-up still takes place. The build-up curves continue, apparently, to the same saturation level. The saturation level is indicated by the dotted line in Figure 52. In the upper range, it apparently is the same as previously measured at 30 frames/sec and depends on beam current.

Application at Low Frame-Rates. Although the measurements show no integration and storage at very low frame-rates, such application may still be possible. One possibility would be to change the target material so as to obtain a longer time-constant. Another probably suitable method would

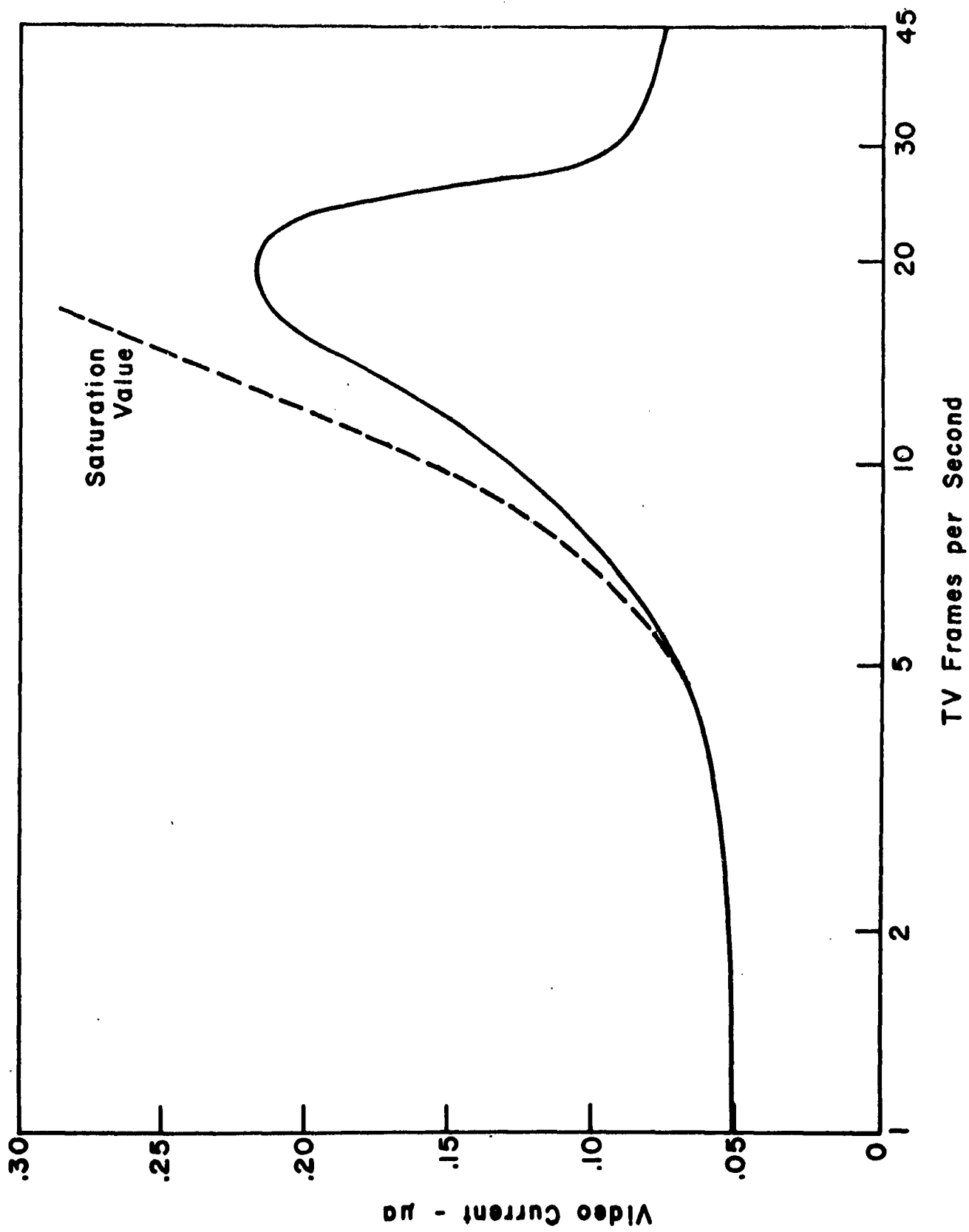


Figure 52. Initial Signal Output Vs. Frame Rate  
with 0.28 Ft.C. Target Illumination

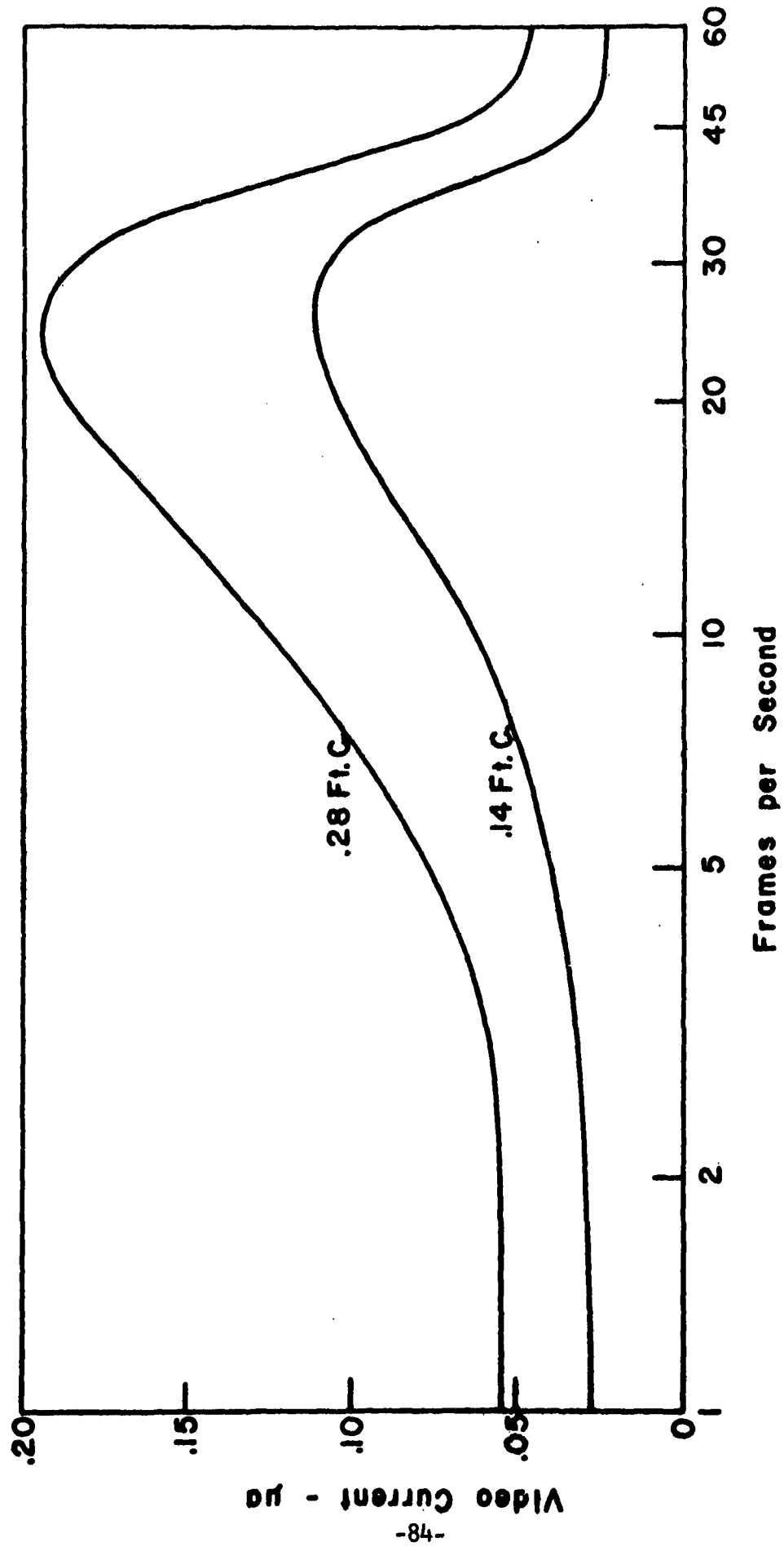


Figure 53. Initial Signal Output Vs. Frame Rate

be to add a flood gun which sprays the entire target uniformly. In electromagnetic tubes this addition involves practical difficulties. In electrostatic tubes it may be feasible. The holding and reading operations being separate, such tubes could be read at any desired scan-rate. The flood-beam current would have to be adjusted to an optimum value so as to be strong enough for maintaining the conductivity produced by previous illumination, but not so strong as to eliminate the charges built up between sweeps, which represent the picture. If these charges are neutralized by a too strong flood-beam, there will be no vacancies to be filled by the electrons of the reading beam and consequently no video output. The possibility exists that such a compromise may be very difficult to adjust for varying light conditions.

Picture Retention. No curve is given showing picture retention after capping the lens. This property appears to be governed by the same function which determines build-up and integration. The storage and integration appear to be constant above 20 frames/sec. and fall off towards low frame-rates. Below about 4 frames/sec there seems to be no build-up and no storage.

Temperature Dependence. A maximum operating temperature of  $45^{\circ}\text{C}$  ( $113^{\circ}\text{F}$ ) is specified for the tube. Even at lower temperatures, however, the dark-current becomes excessive. The present measurements were made in a laboratory which was not air conditioned. The room was, however, well ventilated by means of powerful electric fans. The temperature would during the day occasionally reach  $90-110^{\circ}\text{F}$ . During the summer, measurements could be made only in the early morning (temperature up to  $90^{\circ}\text{F}$ ), and even then the repeatability was barely satisfactory. After only a few measurements in the morning the dark-current would grow to a higher value than the signal-current, which would be slightly lifted but for the greatest part buried in the dark-current. No erasure procedure would be found which would clean the target under these conditions, except switching off the equipment and leaving it until early the following morning.

It should, however, be noted that too low temperature is also unsatisfactory. Time has not permitted comprehensive measurements under such conditions, but it may be mentioned that some readings later at 45°F room temperature gave about 1/3 of the values obtained at normal room-temperature. Considerable drop occurred when capping the lens. (Note: More recent experience has shown that an optimum operating temperature is between 20 and 25°C).

Conclusions. The Permachon integrates the input signal. The output signal therefore builds up with prolonged exposure. Stationary scenes of low brightness can therefore give usable output. When the input is cut off (the lens capped), the output is maintained, although with some reduction of signal strength).

Both initial signal output and build-up are best at normal frame-rates (20 - 30 frames/sec). When the frame-rate is reduced, the output signal decreases, and the tube gradually loses its ability to store and integrate. Below about 4 frames/sec no storage takes place.

At high frame-rates the initial output again falls off, but integration and storage is retained. Most likely there will be little need for Permachons in systems using high frame-rates. The fall-off of the initial value, therefore, is primarily of theoretical interest.

The Permachon performs properly only in a rather narrow temperature range around room-temperature. Below this range both output and storage suffer. Above this range the dark-current becomes excessive and gradually swamps the signals. The tube, then, cannot be properly erased. It appears that the temperature sensitivity restricts utilization of the Permachon more than any other characteristic.

#### Resolution and Other Permachon Characteristics

Subjectively, the image quality produced by the Permachon mounted in an ITV-6 camera appeared at least equivalent to that of the standard one-inch vidicon. Resolution up to 500 lines limiting could be detected on the display of a standard RETMA test chart. The gray-scale rendition was also



comparable, thereby providing an outstanding exposure-integration characteristic.

Quantitative data was also acquired on the Permachon to define more accurately the properties of the device. This was accomplished by exposing the tube to a special test-chart consisting of square-wave resolution patterns and a gray-scale. Proper exposure time was visually determined by uncapping the lens and watching the grey-levels build up to correct balance, after which the lens was capped. Actually, since a larger signal-current is obtained during active exposure than afterward, the observation of a slight over-exposure before lens capping is desirable to provide gray-scale balance of the stored image. This technique can be accomplished reasonably well with practice. After exposure, the square-wave response of the camera is obtained by line-selecting the output video signal with an oscilloscope and measuring the amplitude values for each set of vertical bars on the test chart.

The primary intention of this Permachon evaluation was to obtain data of a relative nature suitable for comparison with a standard vidicon. Therefore, for purposes of expediency, the video signal was measured at the video-output jack of the ITV-6 equipment, instead of at the signal-electrode. The contrast control was adjusted below the value necessary to eliminate overloading of the amplifiers and maintained constant during any related set of runs. Response curves were thereby derived, corresponding to the time immediately after exposure, and also for discrete times thereafter, in order to demonstrate the effect of storage time on image quality. These curves are presented in Figure 54 and, typical of all measurements in this evaluation, represent performance only of the central area of the target.

Permachon storage is characterized by a brightening of the image background with time, accompanied by the consequent loss of contrasts. This effect does not occur uniformly but appears to predominate near the center of the target. Hence, a single line of video, which might appear

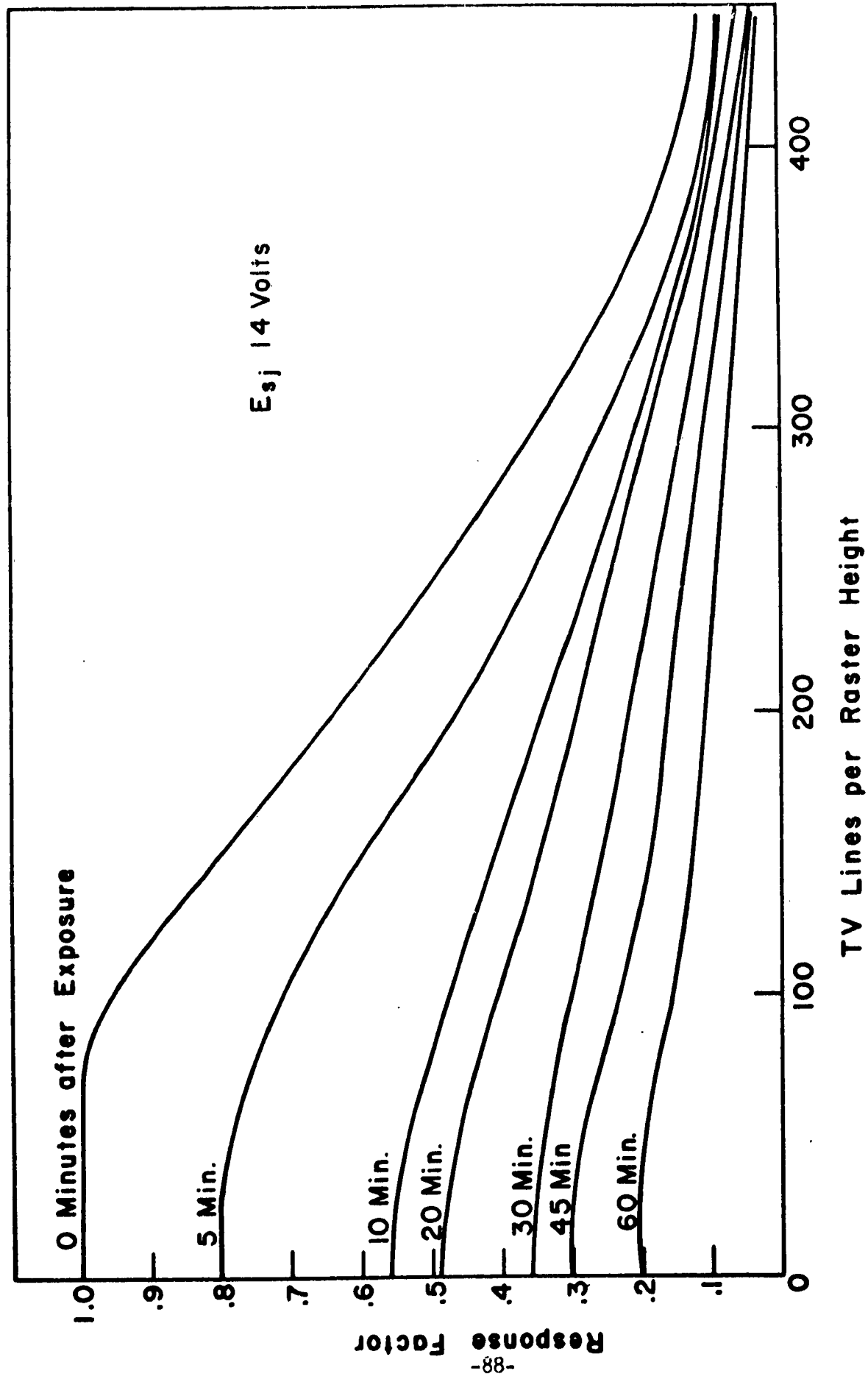


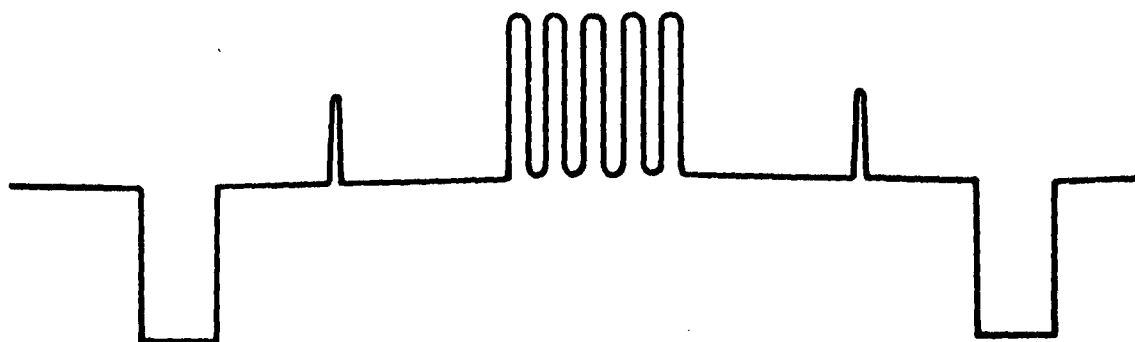
Figure 54. Square - Wave Aperture Response (Permachon)

as in Figure 55 just after exposure, has been observed to deteriorate to the form of Figure 56 with time. The curve of Figure 57 representing shading factor as a function of minutes-after-exposure clearly indicates the build-up effect.

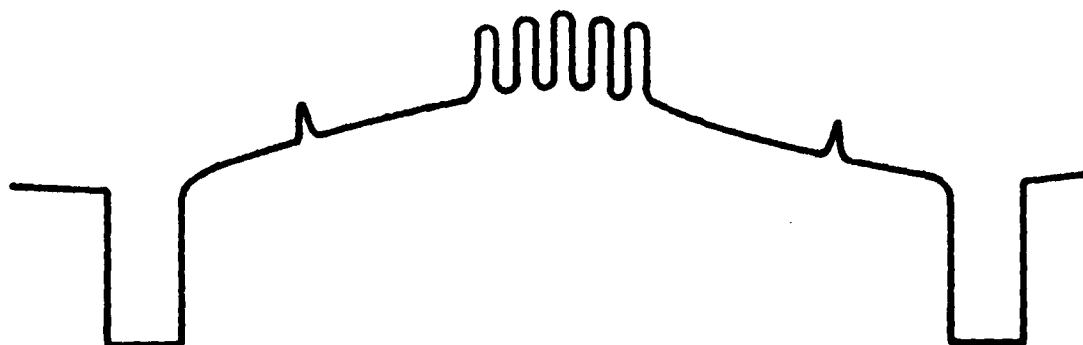
Deterioration of the displayed image with prolonged storage may be partially retarded by appropriate adjustment of monitor contrast and brightness controls. The degree of compensation achievable this way is limited by the non-uniformity of the image background build-up, and also by signal-to-noise deterioration with time. This latter effect is shown by the curve of Figure 58.

The curves of Figure 54 essentially represent the overall response of the ITV-6 camera system, rather than that of the pickup tube alone. Both the optics and the electrical channel characteristic influence the measured aperture-response. As an approximation, the effect of the electrical channel may be minimized in the measurement by appreciably underscanning the exposed target area. This increases the time to scan an equivalent picture element on the target, thereby reducing the bandwidth requirement of the resultant video signal. It should be recognized, however, that the corresponding decrease of pick-up-tube beam-current that must be effected for proper target discharge with the reduced raster can give somewhat misleading results. Consequently, data derived in this manner should be interpreted conservatively. Response curves for the Permachon, measured using the underscanned raster technique, are shown in Figure 59.

As pointed out earlier, the characteristics derived for the Permachon are intended primarily for comparison evaluation. Therefore, corresponding response curves for the 6198 vidicon in the same ITV-6 equipment have been measured and are presented in Figures 60 and 61. The vidicon was operated with the target at 80 volts, in order to obtain the same signal current that the Permachon provided with its target at the recommended 14 volts. However, it should be noted that the vidicon is customarily operated at lower target



**Figure 55. A Line of Video Signal  
Immediately after Exposure**



**Figure 56. A Line of Video Signal  
after Prolonged Storage in Permachon**

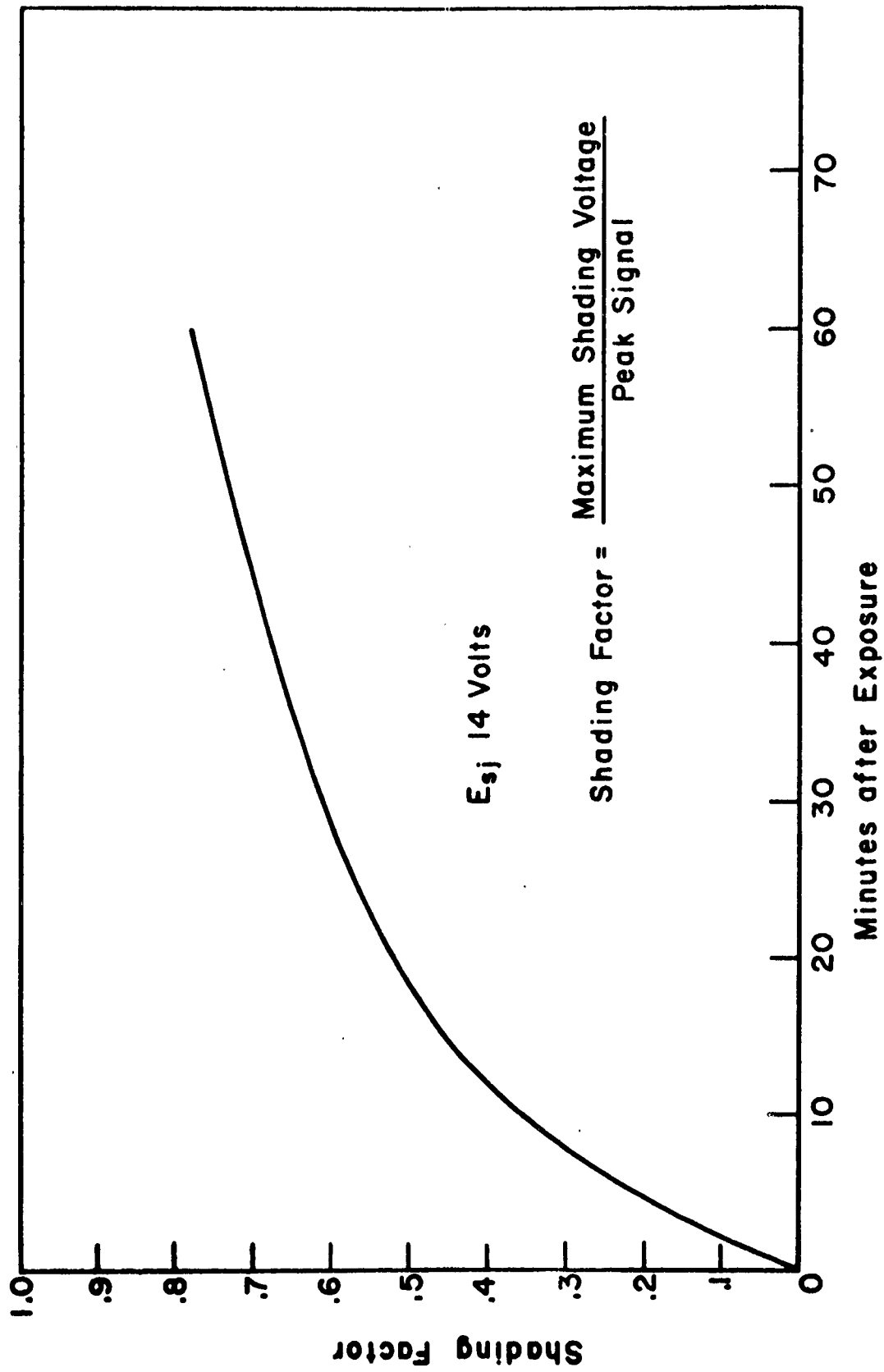


Figure 57. Background Shading Factor (Permachon)

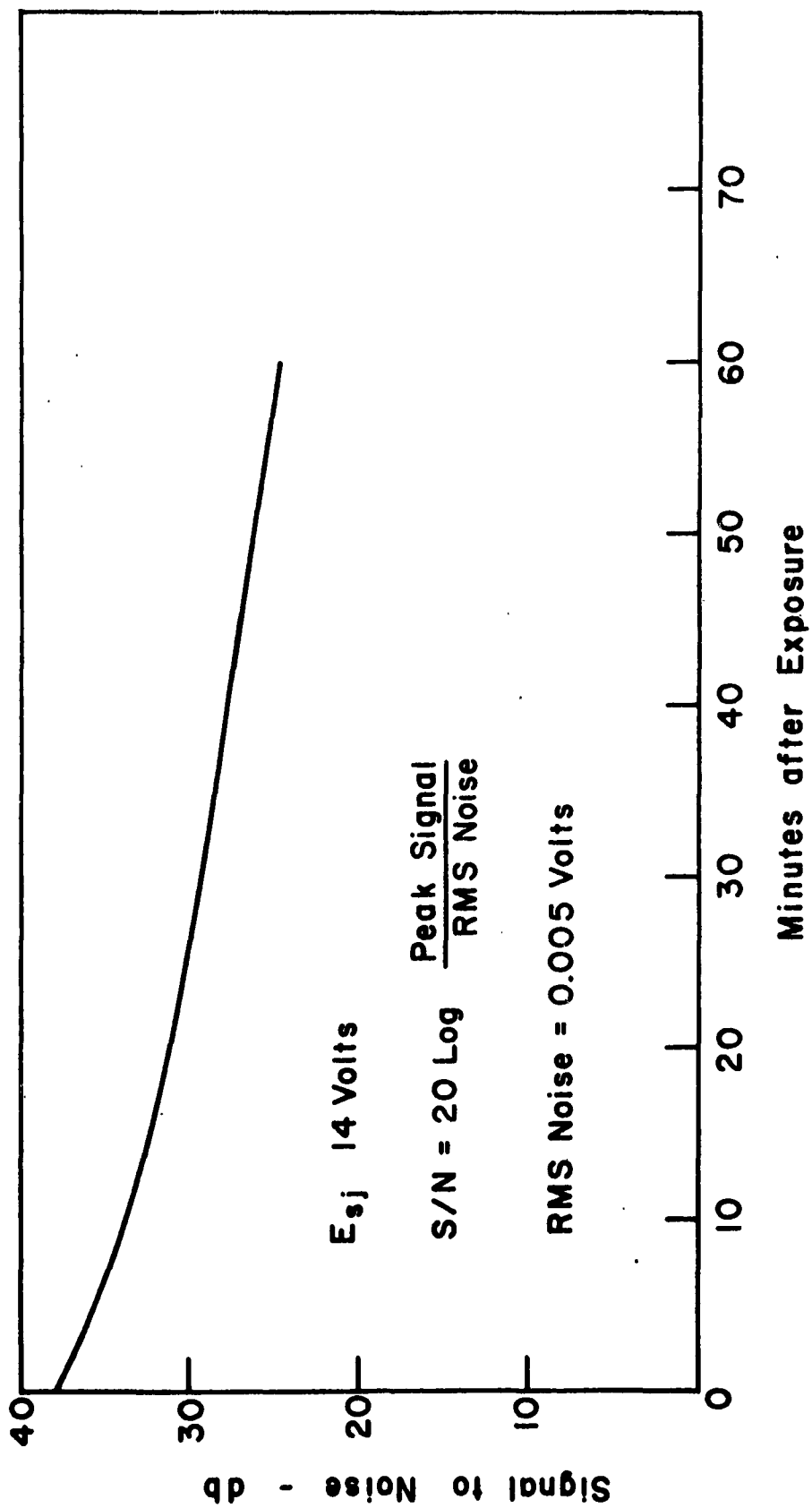


Figure 58. Signal-to-Noise Ratio (Permachon)

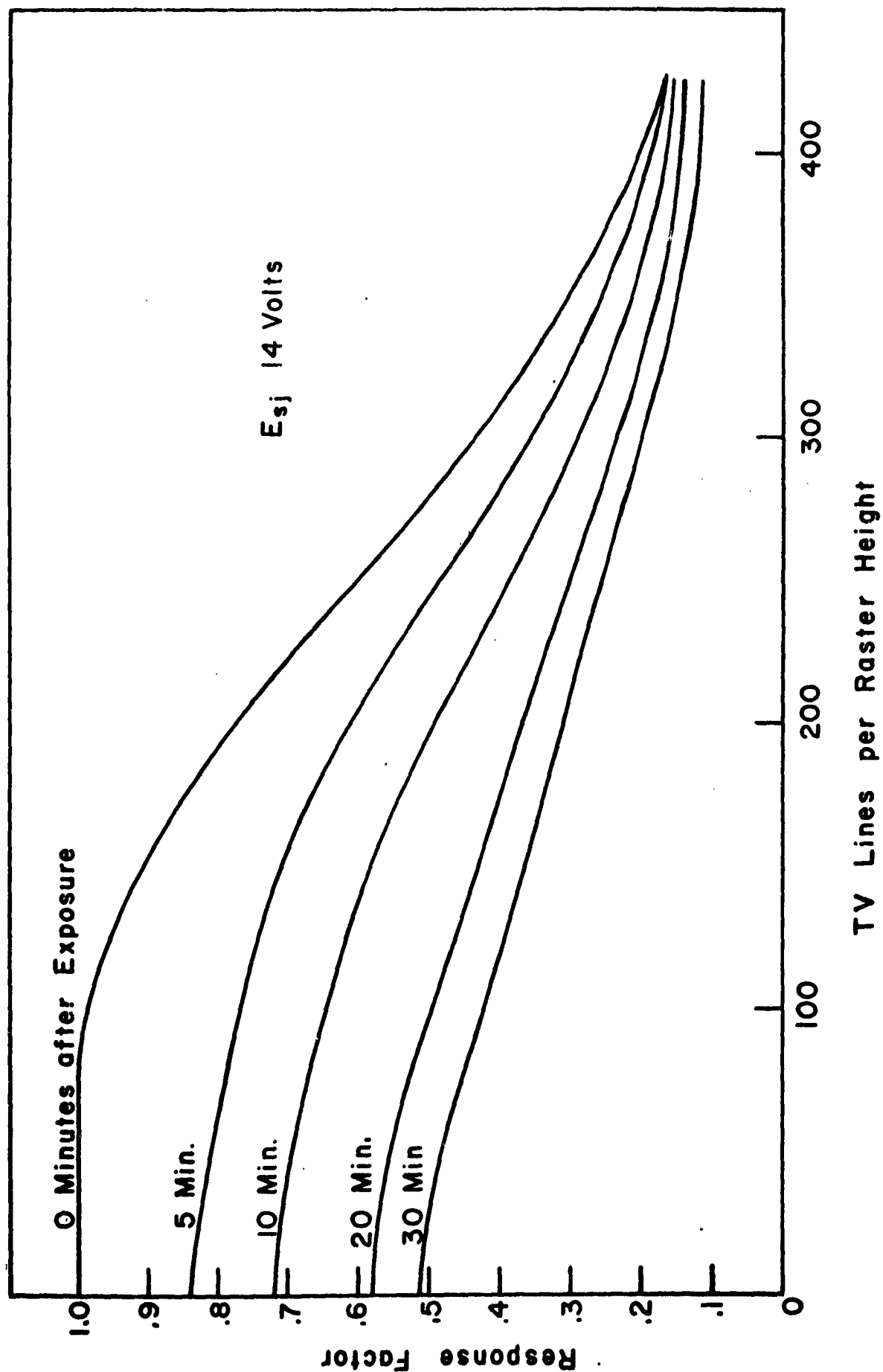


Figure 59. Square-Wave Aperture-Response (Permachon)

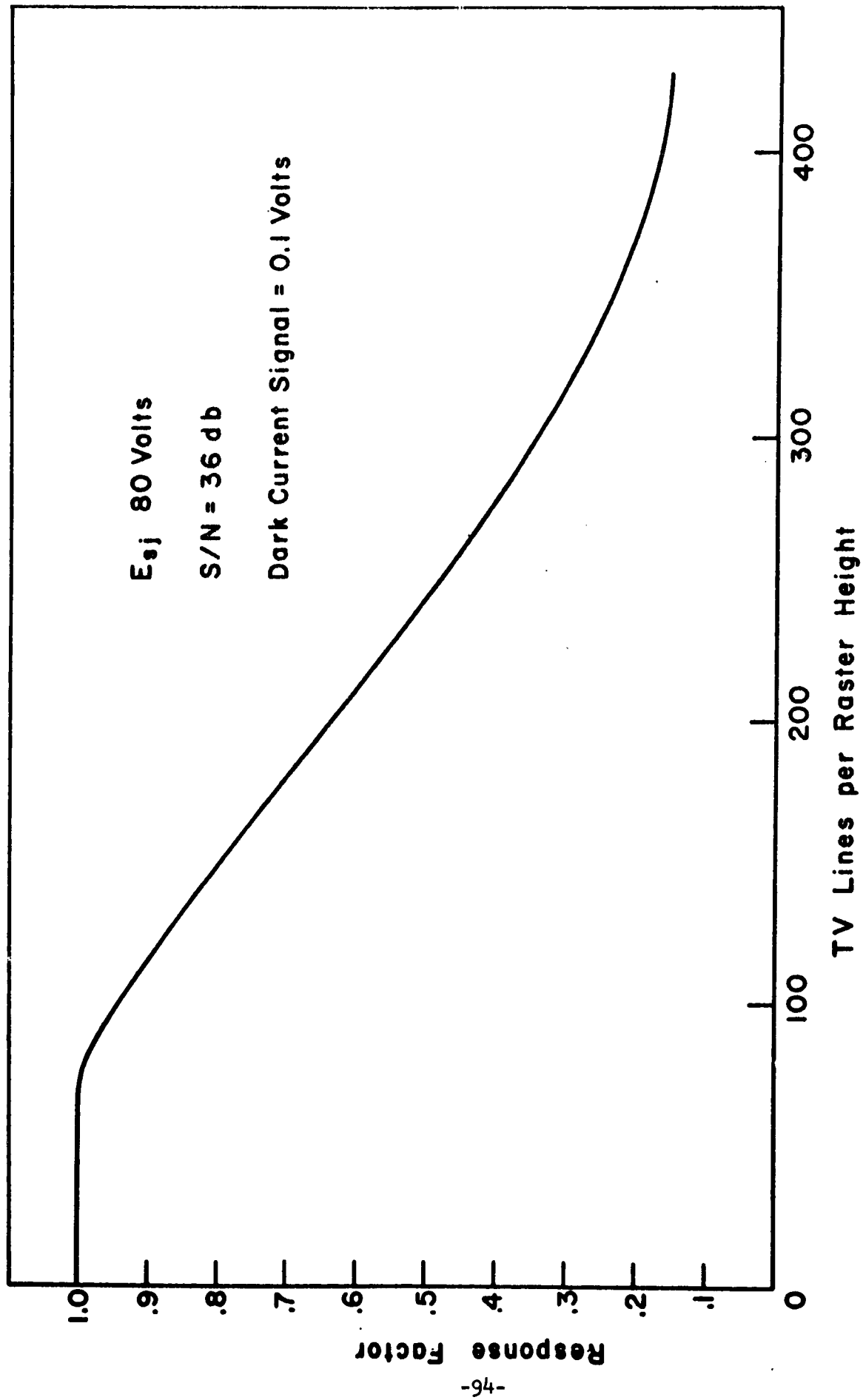


Figure 60. Square-Wave Aperture-Response (6198)



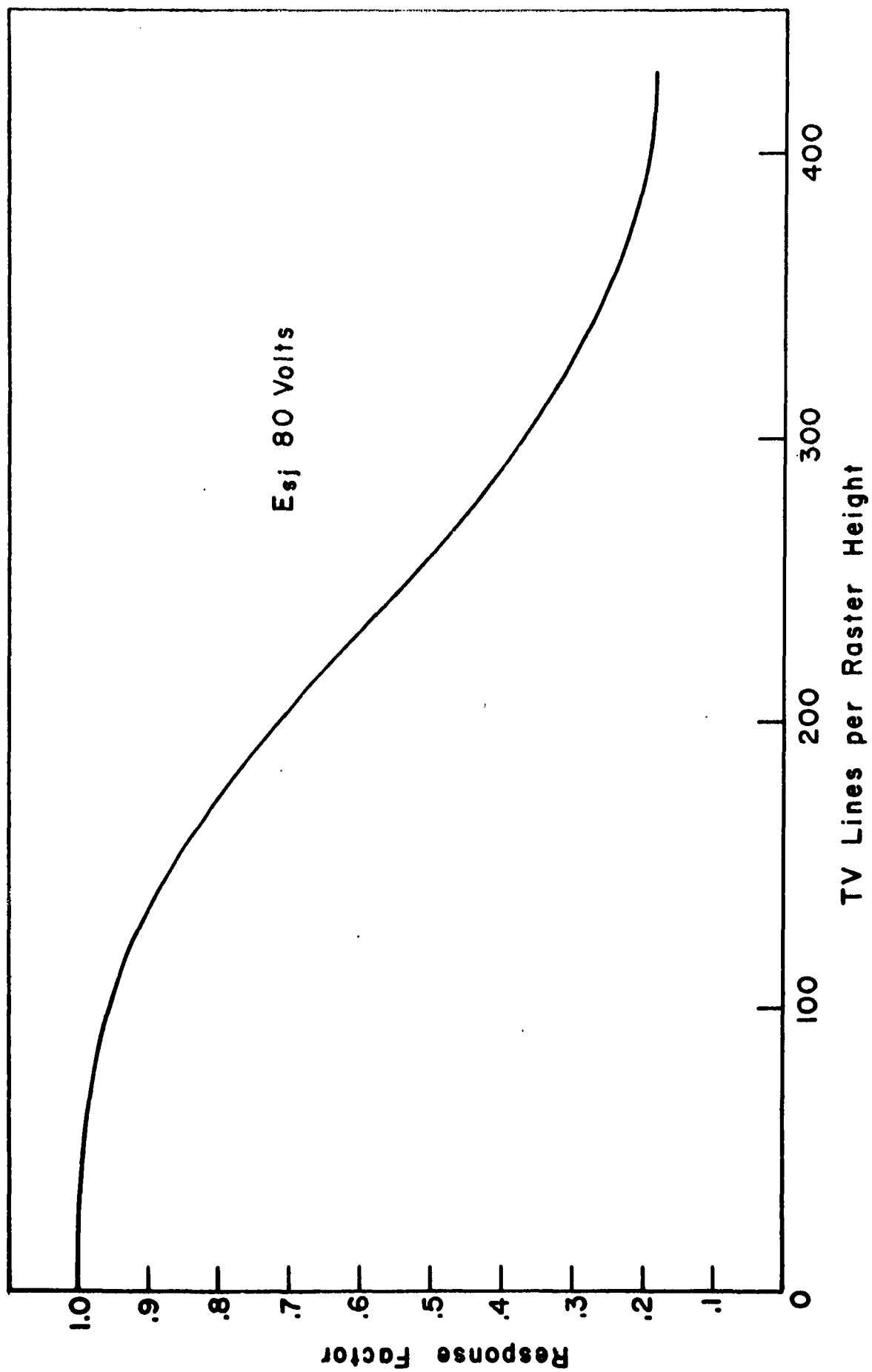


Figure 61. Square-Wave Aperture-Response (6198)

potentials to optimize signal-to-noise for better resolution and improved lag characteristics.

The curves of Figures 54 and 59 represent the square-wave aperture-response. Based on the work of Dr. O. H. Schade of RCA, the sine-wave aperture-response can be of greater value in evaluating the performance of an aperture-limited system. Although this latter characteristic is more difficult to measure for a pick-up tube, it can be approximately determined from the more easily measured square-wave response, provided the beam-aperture shape is known. The vidicon, and consequently Permachon, are considered, as an approximation, to have a circular aperture of gaussian distributed cross-section. Figures 62 and 63 show plots of the square-wave response of this idealized aperture-shape fitted at the half-amplitude points to the measured Permachon and vidicon curves of Figures 59 and 61, respectively. Comparison of these curves indicates a reasonably close correspondence for all other values. Employing the relationships between sine-wave and square-wave response for this idealized aperture, as developed by Dr. Schade in normalized form, the equivalent sine-wave characteristics in Figures 62 and 63 have been calculated, and, as an approximation, may be regarded as the sine-wave response for the reported Permachon and vidicon. From this assumption, the equivalent passband has been calculated at  $N_e = 165$  for the vidicon and  $N_e = 175$  for the Permachon.

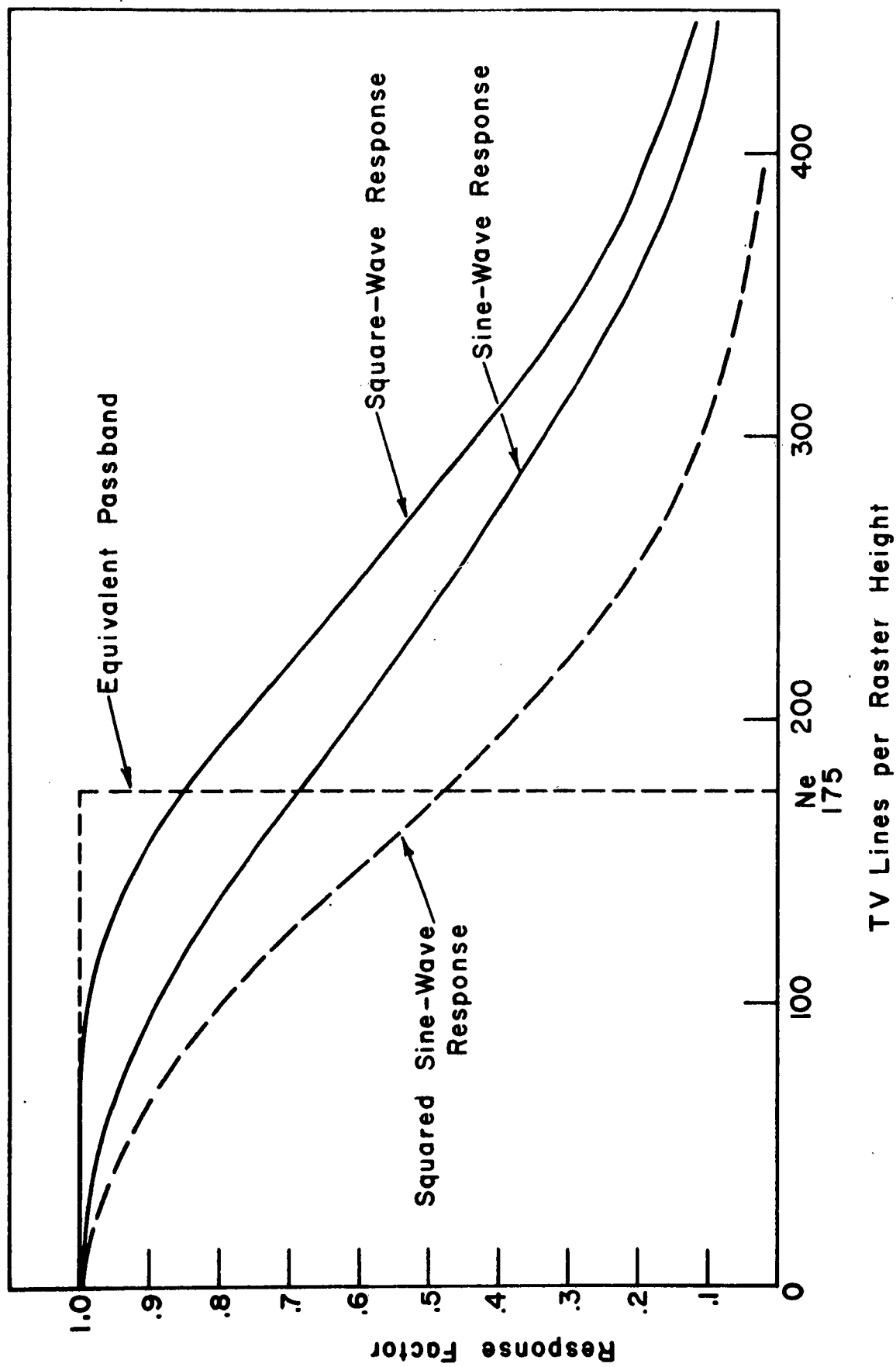


Figure 62. Ideal Aperture-Response Curves for a Circular Aperture of Gaussian Cross-Section Fitted to the Measured Response of a Permachon

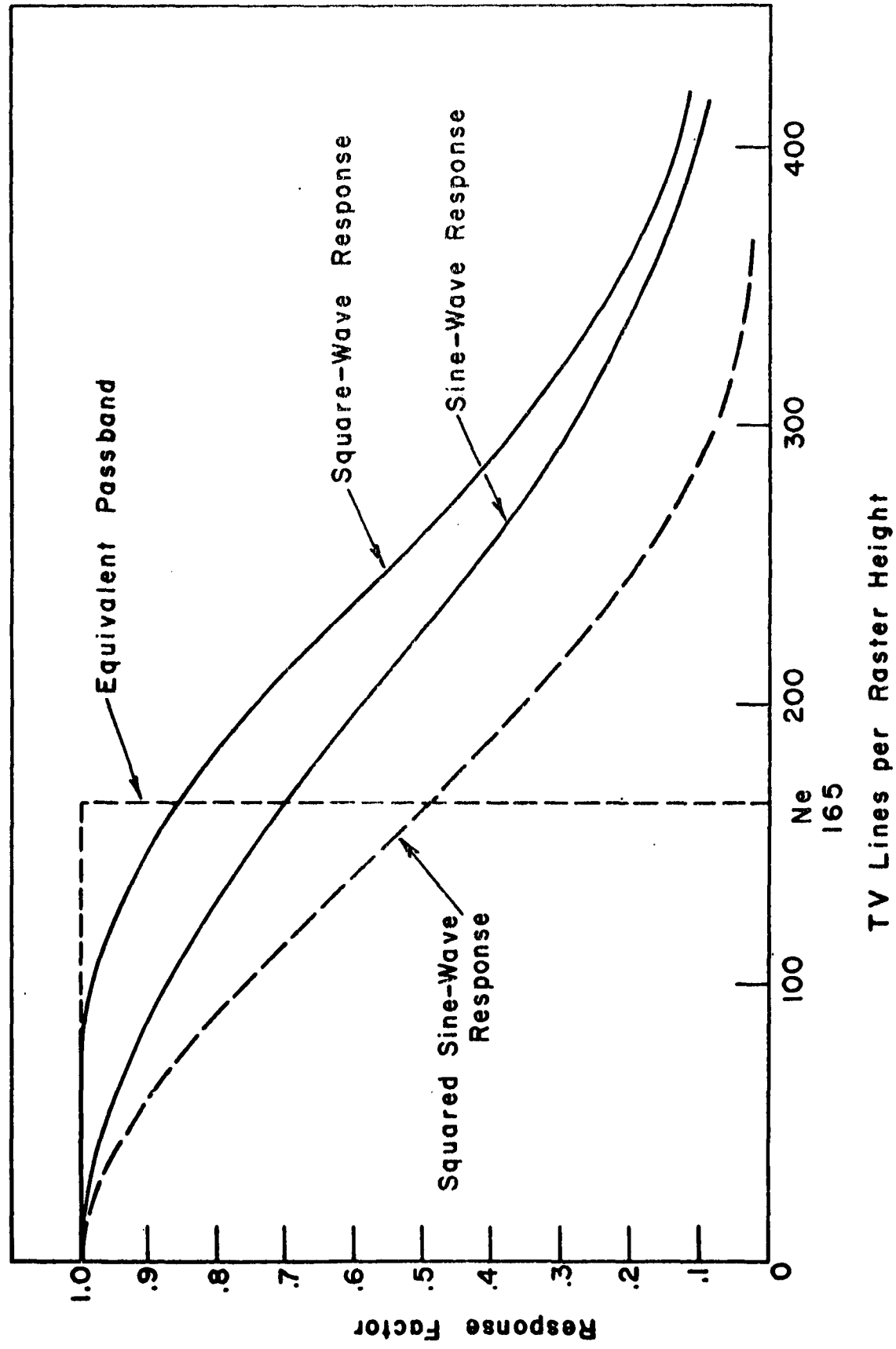


Figure 63. Ideal Aperture-Response Curves for a Circular Aperture of Gaussian Cross-Section Fitted to the Measured Response of a 6198 Vidicon

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SCM-CONVERSION STORAGE TUBE BASED UPON THE  
 PERMACHROM - A. J. Boyle

Final Progress Report, 1 January 1964 to  
 31 March 1964 - 36 pp. - 63 111. In Contract  
 DA-36-039-AMC-00149(E) Task No. 164-22001-A  
 005-03 Unclassified Report

The types of scan-conversion storage tubes based upon  
 the Permachrom camera storage tube have been developed  
 and both tubes utilize a 3/16-inch-diameter useful area.  
 (PRT) target for the signal conversion mechanism.

The emitter of the two tubes, the UT 4800, is 16-1/2  
 inches long, 1-1/2 inches in diameter, and contains an  
 RPT target with a 3/16-inch-diameter useful area. The  
 reading gun in this tube is electromagnetically focused  
 and deflected, while the writing gun is electromagnetically  
 focused and electromagnetically deflected.

The large scan-converter, the UT 4801, is 31 inches  
 long, 3 inches in diameter and has an RPT target with  
 a 3/16-inch-diameter useful area. Both of the electron  
 guns in this tube are electromagnetically focused and  
 deflected.

The UT 4800 has been developed to the point where it  
 could be put into pilot production for utilization in  
 some scan-conversion applications. The UT 4801, a more  
 complex tube, has not been developed to the same extent.  
 This report summarizes all the development work performed  
 on the Permachrom scan-converter, including recently ob-  
 tained data on charge-pump subsequent to creation of  
 the Permachrom scan-converter. The report also includes  
 characteristics measured from the UT 7385 Permachrom  
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- 5. Multi-Medium
- 6. Permachrom Principles
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